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USS *Nimitz* and Carrier Airwing Nine Surge Demonstration

Angelyn Jewell
Maureen A. Wigge
Colleen M. K. Gagnon
Lawrence A. Lynn
Kevin M. Kirk
Kaesey K. Berg
Timothy A. Roberts
Anne J. Hale
Wendell L. Jones
Annette M. Matheny
John O. Hall
Barbara H. Measell

Center for Naval Analyses
4401 Ford Avenue • Alexandria, Virginia 22302-1498

Approved for distribution: Ap

Igor Mikolic-Torreira

Dr. Igor Mikolic-Torreira, Director
Systems and Tactics Team

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A Jewell, et al.

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This paper is the first of a two-volume report in which the analysis of the USS Nimitz and Carrier Airwing Nine Surge operations of July 1997 are documented. This paper focuses on three areas: operational issues, aircraft and ship maintenance and supply issues, and personnel issues. The analysis is a combination of descriptive (narrative of what happened), qualitative (documentation of knowledgeable individual's insights), and quantitative (measured data, such as time expended, amount expended, and sorties generated) assessments. Special attention is paid to the generation and support of strike/fighter sorties.

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Preface

This paper is the first of a two-volume report in which we document our analysis of the USS *Nimitz* and Carrier Airwing Nine Surge operations of July 1997. This paper focuses on three areas: operational issues, aircraft and ship maintenance and supply issues, and personnel issues. Volume 2 of the report contains appendixes A through E which provide additional data supporting our conclusions. Our analysis is a combination of descriptive (narrative of what happened), qualitative (documentation of knowledgeable individuals' insights), and quantitative (measured data, such as time expended, amount expended, and sorties generated) assessments. We pay special attention to the generation and support of strike/fighter sorties.

Summary

On 20 July 1997, as part of JTFEX 97-2, USS *Nimitz* with Commander, Carrier Group Seven (CCG-7) and Carrier Airwing Nine embarked began a high-intensity strike campaign. When they completed flight operations four days later, they had generated 771 strike sorties and had put 1,336 bombs on target.

The Surge, as it has come to be known, was unprecedented. It demonstrated the entire process required to put bombs on target in a littoral warfare scenario; it incorporated all facets of strike warfare—from weapons buildup in the magazines to bombs on target. In the post-Vietnam era, no other carrier and embarked airwing have ever generated as much firepower in ninety-eight hours.

The Center for Naval Analyses supported CCG-7 in the design, data collection, and assessment of the Surge.

What did they do?

Carrier Airwing Nine (CVW-9) flew 975 fixed-wing sorties during the four-day Surge. Figure 1 summarizes the Surge by sortie type and day. Naval Strike and Air Warfare Center (NSAWC) defined the terms:

- A *strike sortie* is one in which the aircraft penetrates hostile territory carrying ordnance; releases ordnance that enters hostile territory; or conducts electronic attack or offensive counterair operations as part of a strike package in which other strike aircraft satisfy the first criteria. Air interdiction, close air support, and suppression of enemy defenses are examples of strike missions.
- A *strike support sortie* is one in which the aircraft performs some function critical to the successful completion of a strike sortie. Tanking, electronic support measures, and combat search and rescue are examples of strike support missions.

- Other sorties include such missions as airborne early warning, defensive counterair, and functional check flights.

Forty-two times during the Surge, aircraft that launched on strike missions did not meet NSAWC's criteria for strike sorties. These sorties are shown as sorties disqualified from strike in the figure.

Figure 1. Sorties flown in the Surge

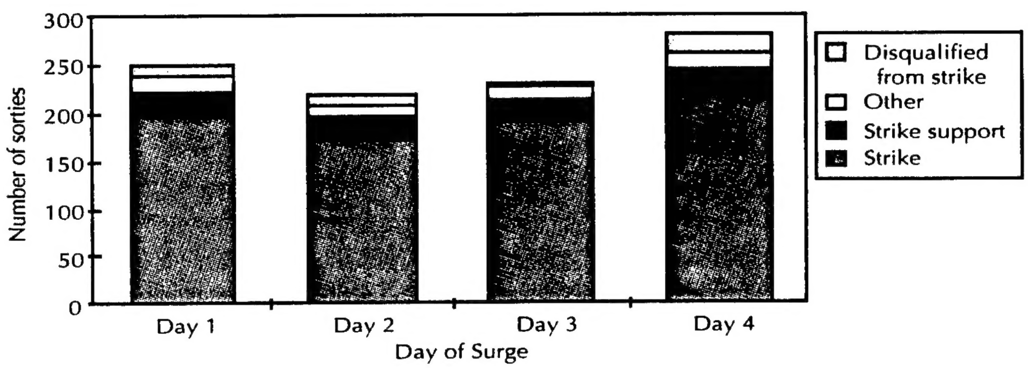
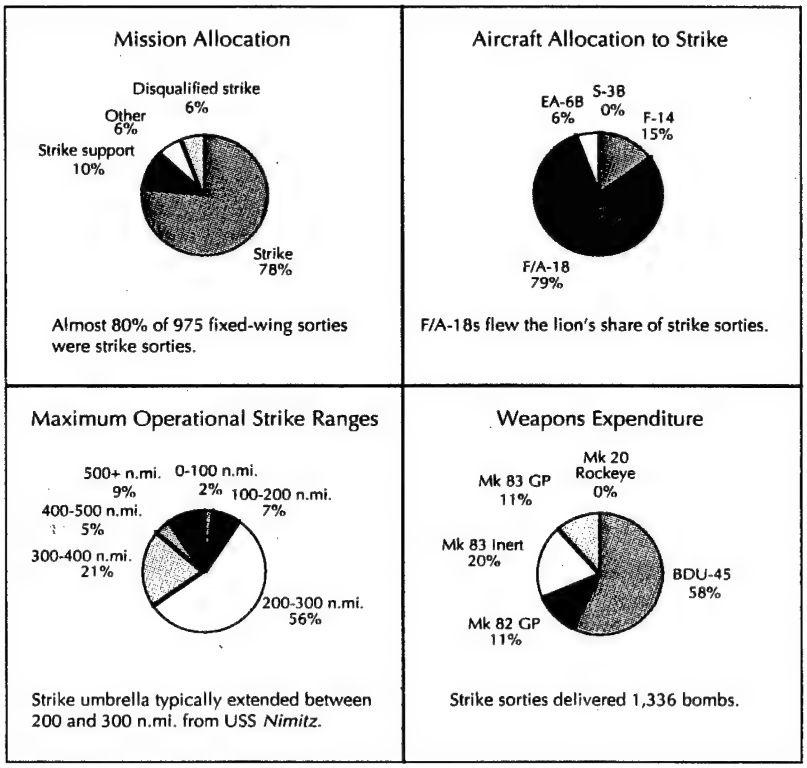


Figure 2 is a composite of several counts. Note that almost 80 percent of the sorties flown during the Surge were strike sorties; strike support accounted for another 10 percent. F/A-18s flew the lion's share of strike sorties—nearly 80 percent. Almost all the targets were within 200 n.mi. of USS *Nimitz.* These distances are not indicative of the maximum striking range of the aircraft, but rather were driven by the proximity of the carrier operating area to the target ranges. We show the maximum operational strike range that the strike/fighters could have reached, based on typical operational employment and time airborne. Weather in the target areas frequently forced strikes to be rolled to secondary targets, exercising the full range of command and control. And for virtually all strike/fighters, the weapons load-out was two 500-pound or 1,000-pound bombs, plus air-to-air weapons. Of the 771 strike sorties, 727 were loaded with bombs; 44 were EA-6B electronic support sorties.

In the Surge scenario, only a portion of the medium-range interdiction strikes required tanking support. KC-135s and KC-130s provided

most of this support. Carrier Airwing Nine S-3s conducted recovery tanking and supplied more than one-third of the fuel passed to CVW-9 aircraft during the Surge.

Figure 2. Box scores



Preparation laid the foundation

The Surge did not occur in isolation. As part of JTFEX 97-2, it was preceded by six days of an intense, event-driven scenario in which the entire *Nimitz* battle group conducted offensive and defensive operations. During these six days USS *Nimitz* and CVW-9 generated about 700 fixed-wing sorties.

Following the six-day period, operations paused for 16 hours, during which USS *Nimitz* and CVW-9 made critical preparations for the Surge:

- The USS *Nimitz* Air Department prepared the flight deck for high-intensity flight operations by: inspecting and conducting routine maintenance on catapult and arresting gear; repainting markings on the flight deck; moving some non-mission-capable aircraft and unneeded equipment from the flight deck to the hangar bay; and configuring the flight deck for the first Surge launch.
- USS *Nimitz* conducted an underway replenishment so that aviation fuel stores were at maximum operational capacity.
- Ordnance crews built up bombs, loaded aircraft for the first two launches of the Surge, and staged weapons in the bomb farm adjacent to *Nimitz*'s island.
- Maintenance personnel worked through the night to repair aircraft, resulting in a mission-capable rate of almost 80 percent.
- Strike leaders planned the initial strikes while aircrews rested.

The result of all this preparation? At the start of the Surge, the aircrews were qualified, ready, and rested; the aircraft were groomed; and the ordnance was staged. The cost? Flight-deck and maintenance personnel began the Surge after six days of nonstop, intense activity and were not rested.

In a real-world scenario, during this operational pause the battle group and amphibious forces would close the littoral, replenish ordnance and fuel, and make similar preparations for combat.

Personnel augmentation was critical

In previous high-intensity flight operations, the capacity to generate sorties was limited by people. In the Surge, it was not. Two hundred and fifty-five active-duty and reserve personnel augmented USS *Nimitz* and CVW-9 for the Surge. We have several recommendations regarding personnel augmentation in future high-intensity flight operations:

- The number of augmentees was artificially high. Some augmentation was required to achieve CV/CVW deployment manning

levels. Exercise planners, cognizant of past fleet experiences, intentionally requested a higher number of augmentees than they thought necessary. Although the Surge placed heavy demands on many personnel groups, some groups—such as ship's laundry, counseling, and engineering—faced normal or below normal workloads. We recommend that the Navy perform a detailed study of the required numbers, qualifications, and currency of augmentee personnel, along with consideration of possible schemes for use of underutilized resident personnel.

- Most flight-deck personnel groups—aircraft directors, plane handlers, chockmen, fueling personnel, and plane captains—were augmented. These groups generally were able to maintain regular work schedules. However, the catapult and arresting gear operators were undermanned. They received no active duty augmentees and were manned well below billets authorized. We recommend these groups be augmented.

- An Operational Strike Planning Cell (OSPC) was created from augmentees to allow the aircrews to focus on mission execution, thereby reducing fatigue among the aircrews. By lowering the time aircrews spent on mission planning, the OSPC also may have enabled the airwing to achieve greater pilot utilization rates. We recommend that future high-intensity strike operations be augmented with an OSPC.

- In all cases, establishing trust between the augmentees and resident personnel was critical to enabling the augmentees to contribute. Where fleet-wide practices were in place—such as the aviation community's acceptance of NSAWC procedures—integration of the augmentees was seamless. Where such procedures were absent, full utilization of augmentees was delayed. We recommend the Navy review fleet practices to identify those that would benefit from standardization.

- In general, we do not recommend augmenting leadership positions (carrier CO, CAG, squadron COs, Handler, and CAGMO). Instead, we recommend that individuals in positions of authority delegate to resident personnel and that

augmentation be provided to assist the resident personnel serving as the leaders' reliefs.

Maintenance and supply met the demand

Fifty-eight scheduled fixed-wing sorties were missed during the Surge; 49 of those were missed for aviation maintenance and supply reasons. A few times a sortie was missed because aircraft would go down just before launch. More often, however, a sortie was missed because of a lack of mission-capable aircraft to fly the mission.

Observed mission-capable rates were consistent with rates reported by other deployed airwings—except for the F-14. The F-14A mission-capable rate during the Surge was substantially lower than rates for recently deployed F-14As.

We examined maintenance turnaround times for both the organizational level (squadron) and intermediate level (AIMD). We found that the biggest contributor to O-level turnaround time was time awaiting maintenance. More O-level maintenance personnel might have increased mission-capable rates, particularly for the F-14 squadron. The biggest contributor to I-level turnaround time was time awaiting parts, which indicates that the inventory of repair parts was insufficient to keep up with demand.

Data indicate a low cannibalization rate across all squadrons. However, we observed the F/A-18 squadrons cannibalizing critical pieces of gear that had inadequate logistic support—the F/A-18 video recorder and the APG-73 radar receiver, for example. The low cannibalization rate may have been an artifact of the short logistics chain.

Could they have done more?

Our analysis indicates that USS *Nimitz* and CVW-9 had the potential to generate additional strike sorties (to exceed the 800 benchmark). Under the Surge master air attack plan (MAAP), they might have made up some of the missed sorties had they more extensively used the Super Spare concept. The cost for this would have been higher aircrew tasking and increased tasking to the maintenance and

servicing crews, but our analysis indicates that they had the reserve capacities to pay these costs.

Further, our analysis reveals that USS *Nimitz* and CVW-9 could have met the demands of a MAAP with a higher sortie-generation requirement. Indeed, USS *Nimitz* and CVW-9 had excess capacity resident within their aircrews and F/A-18 airframes. Based on our calculations, CVW-9 F/A-18 airframes, free of other constraints, could have generated more than an additional 150 sorties. Achieving that potential would have required a few more strike/fighter pilots than present during the Surge. More important, it would have required that the flight-deck crews ready 20 percent more aircraft—a task that would have called for additional ordnance crews, a different flight-deck loading and configuration, and the buildup and transfer of additional ordnance to the flight deck.

Under a more demanding MAAP, the turnaround processes would have been the most constraining factor. In hindsight, the *Nimitz* flight deck probably had the capacity to process at most an additional 50 to 100 strike sorties over the four-day Surge.

The length of time a carrier and its airwing can maintain a high-intensity operating tempo without pausing is also limited. Eventually, scheduled ship maintenance must be performed, maintenance that could disrupt and in some cases halt flight operations. Weekly PMS activities would have allowed the carrier and the airwing to operate for at most three additional days before the conduct of scheduled maintenance would have affected flight operations.

The airwing will eventually deplete the carrier's magazine of ordnance and consume the carrier's supply of usable JP-5. Based on the rates of consumption of ordnance and fuel, we estimate these consumables would have been depleted in about one more day.

The most difficult constraint to measure is that imposed by personnel—that is, the time before exhaustion overtakes individuals. Although we found no evidence that general fatigue was present among aircrews, other personnel groups were undermanned, and fatigue was evident by the final day of the Surge.

Based on these factors, we project that USS *Nimitz* and CVW-9 could have sustained the Surge operating tempo for another 12 to 24 hours.

What else did we find?

- By sharing aircraft, aircrews, maintenance personnel, and ordnance loading crews, the three F/A-18 squadrons can realize the potential for more sorties.
- Under the Surge operating tempo, flight-deck crews found they could routinely manage 27 to 29 aircraft on the flight deck. When the number climbed to over 32, conducting turnaround tasks became more challenging. Operators recommended that in future high-intensity operations the number of aircraft on the flight deck be held to under 30. Continuous flight operations were actually easier to support than had flight operations been halted for a few hours each day.
- Moving weapons from the hangar deck to the flight deck proved to be the most difficult step in transporting weapons from the magazines to the awaiting aircraft.
- Aircraft utilization rates observed during the Surge greatly exceed the Navy's (OPNAV N88) planning factors. We recommend OPNAV modify its planning factors to reflect the dependence on the operational environment and the advances in modern aircraft reliability.
- A few times during the Surge, a 1+00 cycle was included in the air plan. The 1+00 cycle proved exceptionally challenging, nearly forcing the flight deck into flex mode, and it significantly increased the fatigue of flight-deck personnel. Operators felt the 1+00 cycle was too short and that cycle time should have been at least 1+15. On the other hand, to be independent of tanking, F/A-18Cs must operate on cycles of 1+20 or shorter. Therefore, unless nonorganic tankers are available, the cycle time must be between 1+15 and 1+20 at operating tempos comparable to that of Surge.

Preparations for the Surge

The Surge was conducted as part of JTFEX 97-2 in the Southern California operating area. Commander, Third Fleet was the Officer Conducting the Exercise (OCE); Commander, Carrier Group Seven was the embarked battle group commander and Carrier Airwing Nine the embarked airwing; and Commander, Carrier Group Three was the JFACC.

The planning for this exercise was extensive. Carrier Group Seven drew on a multitude of resources: Carrier Group Three established operationally realistic ordnance loadouts; NSAWC defined the attributes of a strike sortie (appendix A of Volume 2, [1]); the plans for the Surge incorporated lessons from past operations with high-intensity operating tempos; close coordination with the Federal Aviation Administration minimized the exercise artificialities of operating in the Southern California operating area; and Commander, Naval Air Forces Pacific provided additional weapons and personnel.

An overarching goal in the planning for the Surge was to make the scenario as realistic as possible, with fidelity in the sortie generation process so that USS *Nimitz* and CVW-9 could demonstrate its firepower potential and at the same time achieve realistic training. The JTFEX scenario mirrored closely that of a Southwest Asia conflict and used real-world intelligence to accurately portray enemy threats, capabilities, and actions. Strike missions were exercised under an Air Tasking Order (ATO) promulgated by a JFACC afloat. The Surge provided much more than a statistical tabulation of sorties on and off USS *Nimitz*; it demonstrated the entire process required to put bombs on target in a littoral warfare scenario.

Commander, Carrier Group Seven asked the Center for Naval Analyses (CNA) to help in several ways: provide analytic support in designing the exercise; collect data; provide real-time assessments of the conduct of the Surge operation; and identify the factors limiting the

firepower potential of USS *Nimitz* and CVW-9 in the exercise scenario. Three objectives guided our analysis:

- Determine the firepower potential of USS *Nimitz* and CVW-9
- Identify the factors that limited sortie generation
- Document the relevant lessons learned.

NSAWC has asked CNA to extend the analysis of the *Nimitz* Surge to other scenarios. Our approach is to identify the factors that constrain carrier surge operations in general. As such, there are two phases to our analysis: analyze the *Nimitz* Surge; and then extend our assessment of sortie generation potential to a variety of scenarios and mission taskings.

Pre-Surge conditions

The Surge was preceded by six days of an intense, event-driven scenario, in which the entire *Nimitz* battle group conducted offensive and defensive operations. During the six days before the Surge, USS *Nimitz* and CVW-9 generated approximately 700 fixed-wing sorties and, as one consequence, achieved battle space dominance. At that point, the battle group was tasked to shape the battlefield by retaining battle space dominance and executing interdiction strikes, and to provide strike support to a Marine amphibious landing.

Flight operations ceased on Saturday 19 July at 2000. During a sixteen-hour operational pause before the Surge began, USS *Nimitz* conducted an underway replenishment, so that aviation fuel stores were at maximum operational capacity. The *Nimitz* battle group's supply auxiliary ship (AE) was unable to participate in the Surge. To compensate for this exercise artificiality, weapons that would have been brought on board during this standdown period were pre-staged on USS *Nimitz*.

During this period, the *Nimitz* Air Department prepared the flight deck for high-intensity flight operations by conducting inspections and routine maintenance on catapult and arresting gear; repainting markings on the flight deck; performing preventative maintenance on aircraft elevators, aviation support equipment, flight deck

electrical systems, weapons elevators, and fire-fighting systems; exchanging some non-mission capable (NMC) aircraft with mission capable (MC) aircraft in the hangar bay; moving unneeded equipment into the hangar bay, and configuring the flight deck for the first Surge launch. Maintenance personnel worked throughout the night to repair aircraft. Ordnance crews built up bombs, loaded aircraft for the first two launches of the Surge, and staged weapons in the bomb farm adjacent to *Nimitz*'s island. Table 1 shows CVW-9 readiness at the start of the Surge and the allocation of aircraft to the flight deck.

Table 1. Status of CVW-9 at start of Surge

Aircraft type	Number of pilots (+augmentees)	Total aircraft assigned	Number of MC aircraft	Number aircraft on flight deck	
				MC aircraft	NMC aircraft[a]
F-14A	20 (+2)	14	9	8	1
F/A-18C	58 (+21)	36	32	27	0
Squadron A	18 (+7)	12	10	9	0
Squadron B	20 (+7)	12	12	9	0
Squadron C	20 (+7)	12	10	9	0
EA-6B	7	4	4	3	0
S-3B	12	8	5	5	2
ES-3A	4	2	0	0	1
E-2C	6[b]	4	4	3	0
Total	107 (+23)	68	54	46	4

a. NMC aircraft on the flight deck were taken to the hangar bay soon after flight operations started.
b. Mission commanders.

Planning the augmentation

Planners for the Surge recognized the potential hazards to both personnel and equipment resulting from the strain of continuous operations. They implemented a twofold strategy to maintain safety: augment those key personnel who would be most susceptible to fatigue; and increase awareness among all personnel on how to best recognize and minimize fatigue (operational risk management).

Personnel augmentation

USS *Nimitz*, Carrier Airwing Nine, and Carrier Group Seven worked together to execute this strategy. They first identified the personnel among the airwing and ship that would be most at risk for fatigue. Table 2 summarizes their findings. Of the approximately 4,700 personnel in the ship and airwing, sixty percent were considered to be at risk.

Table 2. Population most at risk for fatigue

	Population at-risk	Personnel groups
USS *Nimitz* Department		
Air	457	All
Engineering	20	O2N2 plant operators, elevators, catapult steam operators, A&O
Safety	9	All
Operations	36	Controllers, CTAPS operators, intelligence specialists
AIMD	390	All
Weapons	223	All
Navigation	23	All
CVW-9	1,728	All
Total	2,886	

USS *Nimitz* and CVW-9 were aware that in past fleet experiences with high-intensity flight operations, personnel had always been cited as the limiting factor. Command guidance to *Nimitz* departments and airwing squadrons was to derive a list of desired augmentees and to purposely overestimate the numbers of personnel needed. The V-2 division (launch and recovery operations) declined augmentation, preferring instead to manage with only their resident personnel. Due to their concern for safety, the V-2 division was reluctant to share the responsibility inherent in their jobs with individuals unknown to them. The fundamental difficulty in incorporating augmentees into V-2 operations was the variance among carriers in flight deck procedures. We recommend standardized procedures be developed for use by the V-2 division. Greater standardization among carriers would

ease integration of personnel in much the same manner as the introduction of NSAWC's strike syllabus has brought cohesion to strike warfare execution.

The list of augmentees who participated in the Surge is given in table 3. USS *Nimitz* and CVW-9 did not receive all the augmentation they requested. Reservists constituted about twenty percent of the augmentees, with most of these personnel assigned to AIMD. Most of the ship augmentees embarked USS *Nimitz* six days before the Surge for familiarization and indoctrination training. Most aircrew and strike planners flew on board forty-eight to seventy-two hours before the Surge, simulating their arrival in the contingency theater. While most of the augmentees came from CVW-14 and USS *Abraham Lincoln*, the next-ready battle group, the exercise was not intended to evaluate either the real-world sources for these personnel or the logistics required to transport these personnel to the operating area.

Table 3. Augmentee list

Command	Unit	Position	Rank/Rate	Augmentees Active	Augmentees Reserve
CVW-9	F-14 squadron	Pilots	O-4, O-3	1	1
CVW-9	F-14 squadron	RIOs	O-4, O-3	5	1
CVW-9	F/A-18 squadron	Pilots	O-4, O-3	7	
CVW-9	F/A-18 squadron	Pilots	O-4, O-3	7	
CVW-9	F/A-18 squadron	Pilots	O-4, O-3	7	
CVW-9	F/A-18 squadron	Ordnance personnel	AOAN-AOC	22	8
CVW-9	F-14 squadron	Ordnance personnel	AO3-AOCS	8	
CVW-9	F/A-18 squadron	Plane captains	AN	12	
CVW-9	F-14 squadron	Plane captains	AN	2	
CVW-9	E-2 squadron	CICOs	O-3	4	
CVW-9	E-2 squadron	Electronics technicians	AT2, AT3	2	
CVW-9	E-2 squadron	Aviation machinists	AD3, AD1	3	
CVW-9	E-2 squadron	Aviation electricians	AE3	2	
CVW-9	HS squadron	Aviation machinists	AD1, AD2	2	
CVW-9	Staff	Landing signal officers	O-3	5	
CVW-9	Staff	Air intelligence officers	O-2, O-3	3	
CVW-9	Staff	Strike cell planners	O-1 through O-6	6	4
USS *Nimitz*	Air Dept.	Air Boss	O-5	1	
USS *Nimitz*	Air Dept.	Mini Boss	O-5	1	
USS *Nimitz*	Air Dept.	Catapult officers	O-3	2	
USS *Nimitz*	Air Dept.	Aircraft directors	ABH3, ABH2, ABH111	12	4
USS *Nimitz*	Air Dept.	Aviation boatswain's mates	AN, ABH3	20	
USS *Nimitz*	Air Dept.	Fueling personnel	ABF3, AN	12	1
USS *Nimitz*	Air Dept.	Tower operators	ABH3, AN	5	
USS *Nimitz*	Air Dept.	V-2 personnel	ABE3		1
USS *Nimitz*	Air Dept.	Flight deck caller	O-4		1
USS *Nimitz*	Weapons	Ordnance personnel	AO3, AO2, AOC	10	6
USS *Nimitz*	Operations	Assistant Air Operations Officer	O-5	1	
USS *Nimitz*	Operations	Assistant Strike Operations Officer	O-4	1	
USS *Nimitz*	Operations	CTAPS Administrator	O-5		1
USS *Nimitz*	Operations	CTAPS operators	AC2, AC3	2	
USS *Nimitz*	Operations	Air traffic controllers	AC1	4	
USS *Nimitz*	Operations	Air intercept controllers	OS1, OS2	4	
USS *Nimitz*	Operations	Intelligence officers	O-3, O-4	4	
USS *Nimitz*	Operations	Intelligence specialists	IS1, IS2, IS3	4	
USS *Nimitz*	Operations	USAF intelligence debriefers		2	
USS *Nimitz*	Operations	USMC liaison		1	
USS *Nimitz*	Operations	Operations specialist	OS2		1
USS *Nimitz*	Operations		O-4		1
USS *Nimitz*	AIMD	Aviation support technicians	AS3, AS2, AS1	10	1
USS *Nimitz*	AIMD	Aviation electronics technicians	AT3, AT2		9
USS *Nimitz*	AIMD	Aviation electricians	AE3, AE1		2
USS *Nimitz*	AIMD	Structural mechanics	AMS3, AMSAN		8
USS *Nimitz*	AIMD	Aviation machinists	AD3		2
USS *Nimitz*	AIMD	Maintenance administrator	AZ3		1
USS *Nimitz*	AIMD	Hydraulics mechanic	AMH2		1
USS *Nimitz*	AIMD		O-4		1
USS *Nimitz*	Medical	Hospital corpsman	HM2		1
USS *Nimitz*	Supply		SN		1
USS *Nimitz*	Supply	Aviation storekeepers	AK3, AKAN		6
Total				204	53

During peacetime, the level of manning specified by the number of billets authorized (BA) establishes the manning requirements for each job type. Currently, actual manning is typically about five percent below the BA level. In figures 3 through 7, we compare the numbers of personnel on board with BA.[1] The data for each job type include all enlisted personnel with the appropriate rating plus any undesignated personnel that may be assigned for support. Figure 3 summarizes the data for the Air Department. Figure 4 details the personnel in the aircraft directors and handlers category (V-1 Division). This category includes all enlisted personnel with an ABH (Aviation boatswain, aircraft handling) rating, from Airman to Master Chief Petty Officer, along with undesignated Airmen.

Figure 5 shows the manning for the V-2 Division. The greatest manning shortfall occurs within the undesignated Airmen category. Shortages of undesignated Airmen were common throughout all departments that had undesignated Airmen assigned to them. Many of the augmentees, however, were slated to make up for this shortfall. Even with augmentation, both the launch and recovery personnel (V-2 Division) and the fueling personnel (V-4 Division) had fewer personnel on board than BA.

Figure 6 summarizes the manning for key enlisted positions within the airwing. Including the augmentees, the maintenance personnel groups were near or slightly above the number of billets authorized. However, similar to the Air Department, there was a large shortfall in the number of undesignated Airmen, many of whom serve as plane captains. In fact, even with the augmentees, the manning for undesignated Airmen within the airwing was only sixty-four percent of BA. In contrast, the ordnance personnel received the greatest number of augmentees, with manning at 134 percent of BA.

In figure 7, we summarize the pilot manning for all squadrons. The pilot manning for all the fixed-wing squadrons was above BA. Pilot manning was higher than deployment levels since some pilots

1. We determine the manning levels, BA, and current on board (COB) for the various personnel groups from the July enlisted personnel report (EDVR) and the officer personnel report (OCDR).

scheduled to detach before deployment were still present. In addition, the number of pilots on board include commanding officers and executive officers from the EA-6B, S-3, and F-14 squadrons, who are not counted in the BA because these personnel may not necessarily be pilots.

Figure 3. Air Department manning (enlisted personnel)

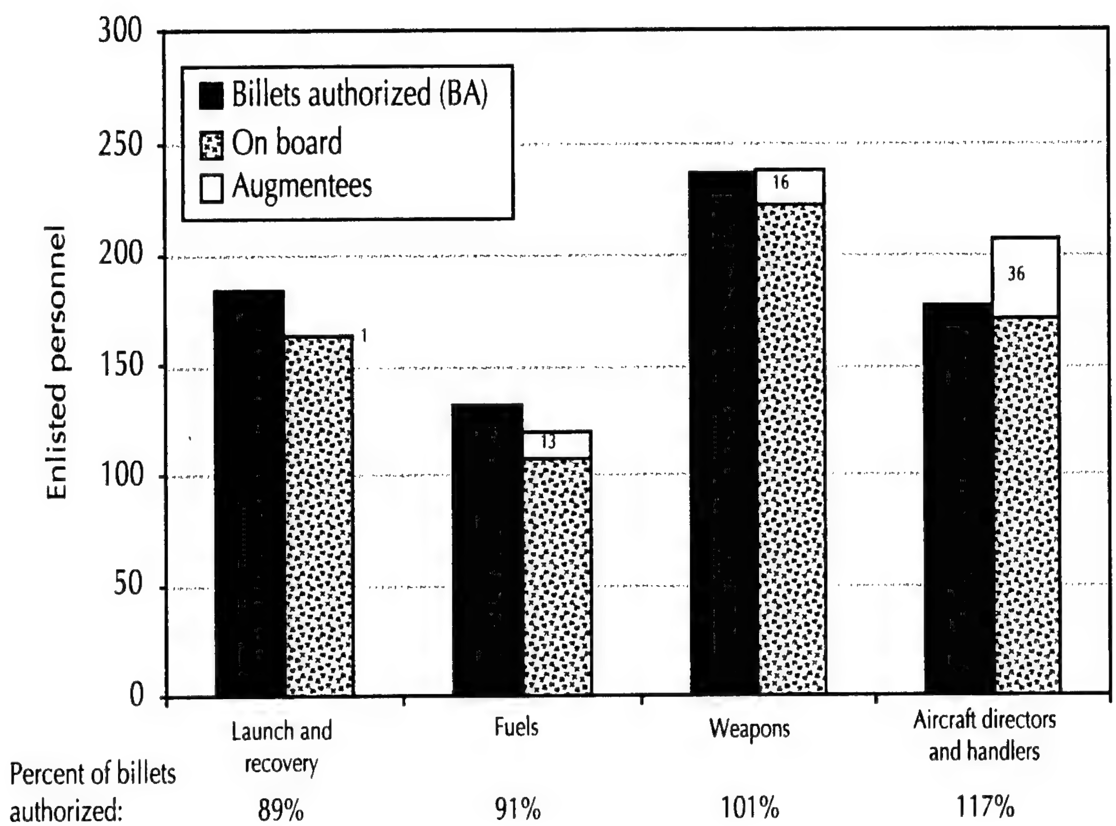


Figure 4. Aircraft directors and handlers (V-1 division)

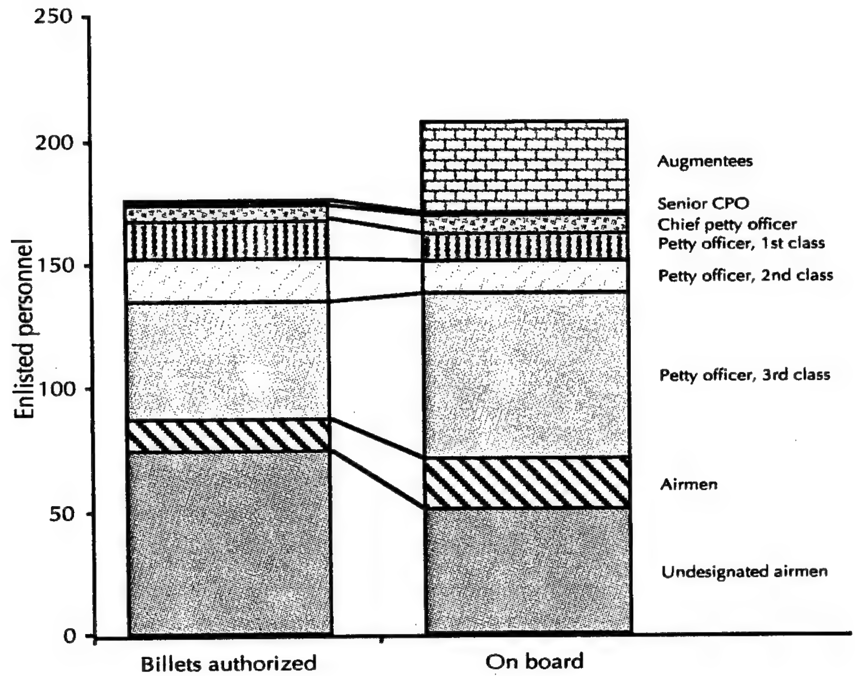


Figure 5. Catapult and arresting gear personnel (V-2 division)

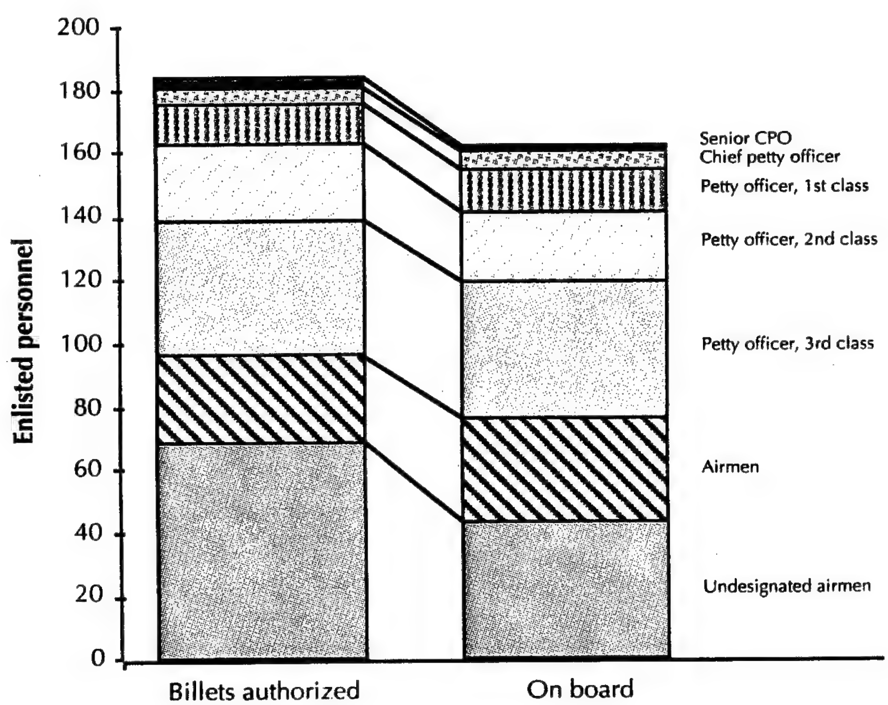


Figure 6. Airwing manning (enlisted personnel)

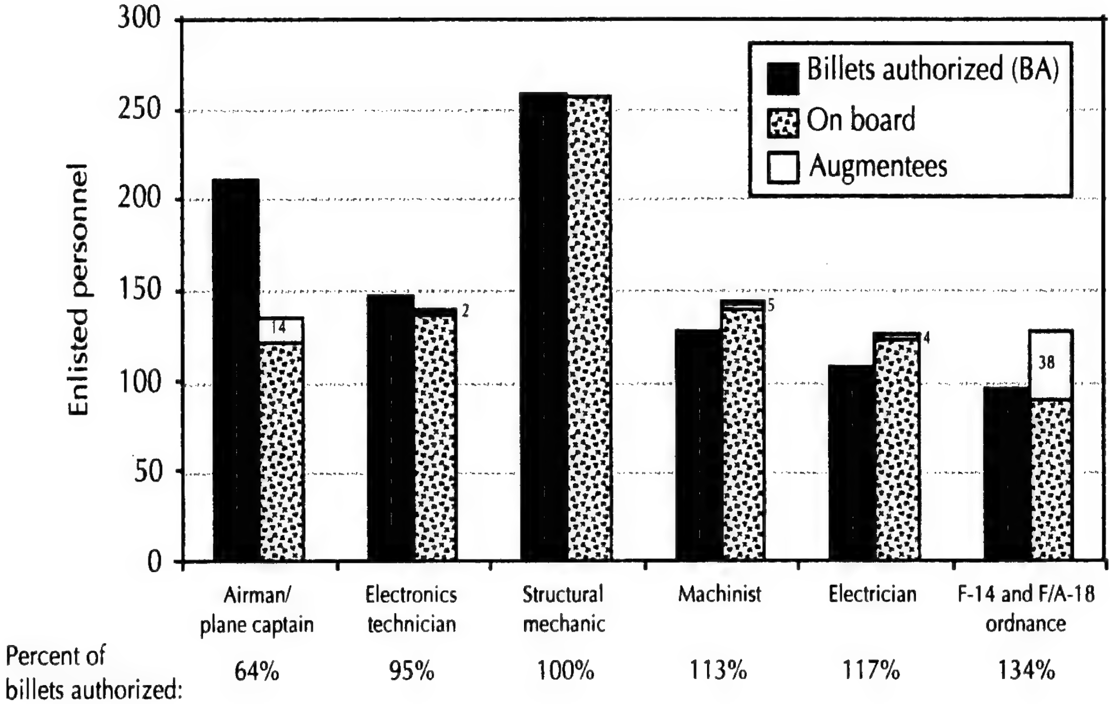


Figure 7. Pilots manning

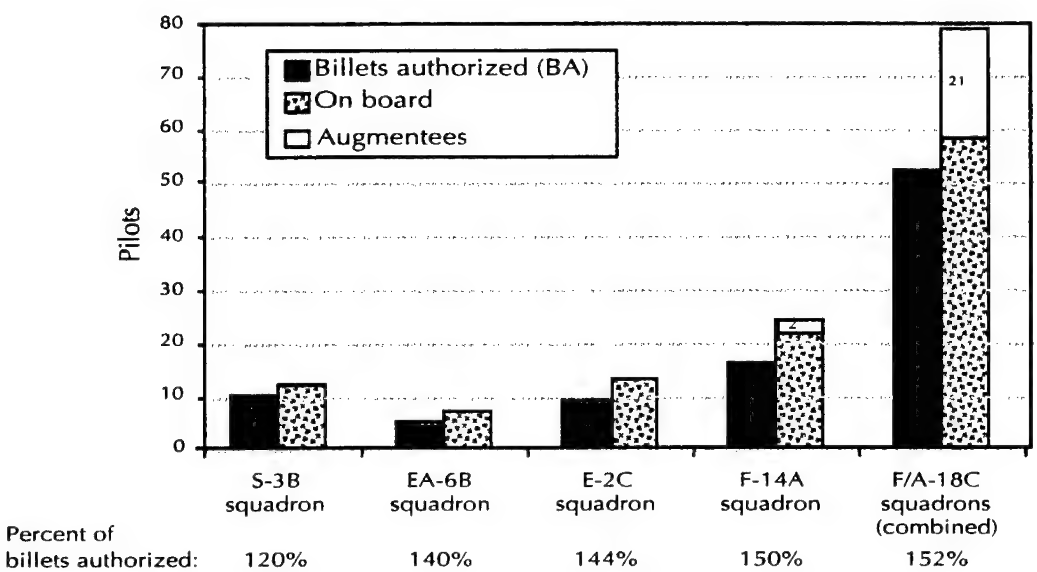
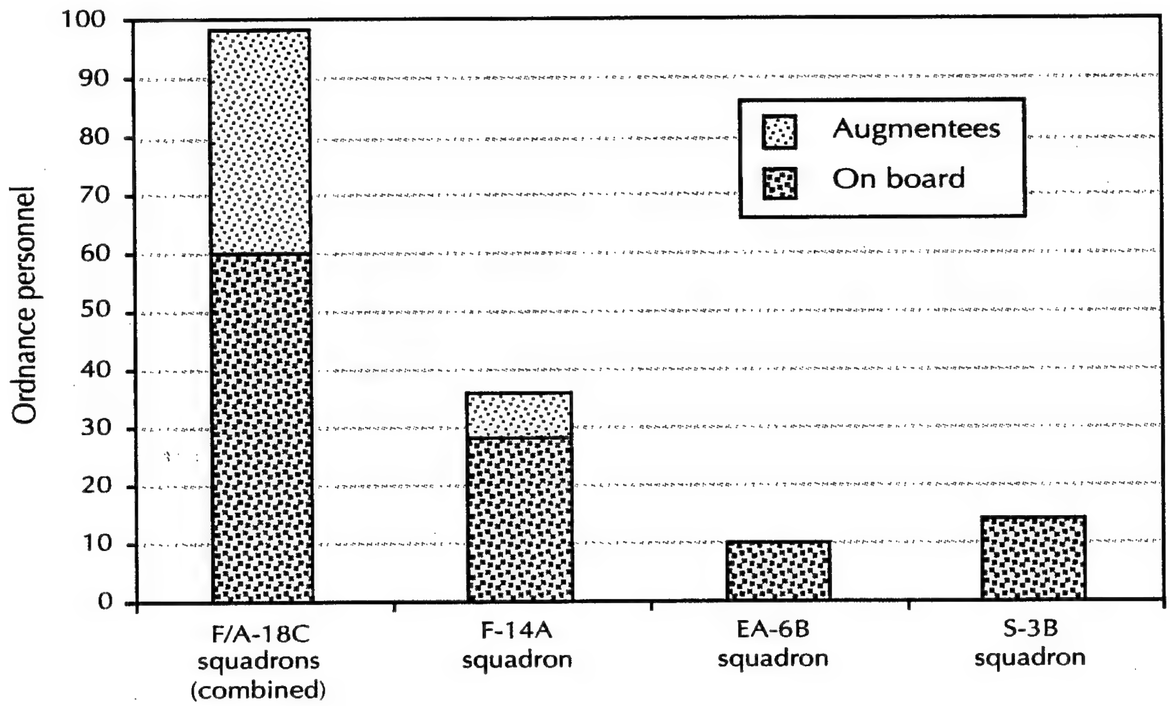


Figure 8 shows the airwing ordnance personnel. The three F/A-18 squadrons collectively received thirty augmentees while the F-14 squadron received eight augmentees. The additional augmentees allowed the F/A-18 squadrons to evenly divide their personnel into two fifteen-man crews each working a 12-on/12-off schedule.

Figure 8. Airwing ordnance personnel



Operational risk management

To better understand the causes of fatigue and how to best counteract its effects, the *Nimitz* Medical Department conducted an extensive study [2] of fatigue before the Surge. Appendix B (Volume 2) reviews their major findings of the effects and causes of fatigue.

Based on their review of the literature and in view of the unique features of the Surge, the *Nimitz* Medical Department proposed a

number of fatigue countermeasures that were subsequently incorporated into the Surge:

- Go into the Surge well rested. A person sleeping less than his daily requirement accumulates a sleep debt measured in cumulative hours. Personnel should try to eliminate any sleep debt before the Surge.

  — The sixteen-hour operational pause preceding the Surge allowed many individuals to rest.

- Schedule and allow naps. Naps reduce one of the predictors of fatigue, the number of hours of continuous wakefulness. Naps of even ten to twenty minutes have been shown to restore some performance.

  — A policy permitting personnel to take naps in safe places in work areas was put in force.

- Pre-plan events and minimize last-minute changes. The effect of fatigue on complex decision-making is striking. To the extent possible, courses of action should be planned in advance to avoid situations that require mental creativity.

  — During the nine months of planning that preceded the Surge, USS *Nimitz* and CVW-9 personnel conducted extensive contingency planning.

- Schedule events in anticipation of circadian cycle effects. A major decrease in alertness occurs between 0300 and 0500 daily as a result of the body's natural rhythm. Stressful activities should be avoided during this time period.

  — The operating tempo was intentionally reduced during these early morning hours to reduce the stress on aircrew.

- If shift work is required, maintain or extend the work day. Shifting from day to night or simply shifting one's work/sleep cycle by a few hours can cause external and internal desynchronization of an individual's internal clock, resulting in fatigue. However, extending the work day is, in general, easier than reducing the work day by an equal amount.

— Exercise artificialities made it difficult for CVW-9 to follow this countermeasure. In the six days before the Surge, the airwing flew on board, carrier-qualified its pilots for both day and night operations, and conducted intensive flight operations as part of the JTFEX scenario. The time was too short for aircrews to fully transition to different work schedules. (Interestingly, this was the only source of complaint regarding fatigue by the aircrews.)

- Minimize administrative and other non-critical duties. By reducing or postponing tasks that do not directly contribute to the creation of firepower, personnel can have additional time for rest.

  — USS *Nimitz* cancelled cleaning stations, inspections, and most administrative meetings.

- Ensure easy availability of food. Personnel will require food at non-standard times. Departments should anticipate this need, and ensure easy access to meals at all times.

  — Galleys were open twenty-four hours a day and hot food was provided at satellite feeding areas in various work centers.

- Reduce unnecessary interruptions to rest.

  — Use of the 1MC was limited to only critical announcements. Man overboard and fire drills were suspended.

- Monitor fatigue and know when to quit. Personnel and their supervisors must acknowledge when they or their workers are fatigued and get some sleep. While everyone should understand the causes of fatigue and its effects, fatigue is difficult to self-monitor; hence, supervisors need to be especially aware of its symptoms among their workers.

  — Squadron medical personnel monitored aircrew fatigue and *Nimitz* Safety and Medical officers monitored flight deck personnel fatigue. USS *Nimitz* also employed a series of surveys that allowed individuals to gauge, in real-time, their perceived fatigue.

Operations during the Surge

The elements that produced the firepower generated in the Surge—the aircrew, aircraft, and the ability of the flight deck to ready aircraft for launch—are the building blocks of sortie generation. We discuss here how those elements were employed. We also include a discussion of CVW-9 employment of a non-standard recovery pattern during the Surge and whether this pattern affected sortie generation. We also discuss how operating from a nuclear-powered carrier affected sortie generation. We begin with a summary of the Surge operations.

Summary

Sorties generated

Carrier Airwing Nine flew 975 fixed-wing sorties during the Surge. Table 4 shows the allocation of sorties to missions in the Surge. (In this paper, the time periods COMEX-211200 July, 211200-221200 July, 221200-231200 July, and 231200 July-FINEX are referred to as Day 1, Day 2, Day 3, and Day 4, respectively.) The scenario in which the Surge was conducted allowed the *Nimitz* battle group to devote almost eighty percent of the sorties flown to strike missions, delivering weapons to targets or directly supporting the delivery of weapons. Strike support missions were allocated approximately another ten percent.

The tallies for Day 2 are the lowest of the four-day Surge. The reduced sortie total is not indicative of a difference in the observed operating tempo. Instead, it is because a launch occurred just before the end of the first day and just after the beginning of the third day. As a result, Day 2 had one less launch. The sortie generation over the first three days of the Surge was, in essence, constant. The last day did see an increased operating tempo, only part of which was called for in the

Table 4. Sorties flown by mission and day

Missions[a]	Day 1	Day 2	Day 3	Day 4	Total	Percent of all sorties
Strike						
AI	114	93	108	71	386	39.6
CAS	46	48	53	115	262	26.8
INT	15	14	12	14	55	5.6
OCA	8	6	6	4	24	2.5
SEAD	11	11	10	12	44	4.8
Strike sub-total	194	172	189	216	771	79.3
Strike support						
ES	3	4	2	3	12	1.2
MTNK	21	18	20	24	83	8.5
TARPS	3	2	2	2	9	0.9
Strike support sub-total	27	24	24	29	104	10.6
Other						
AEW	7	7	7	7	28	2.8
DCA[b]	3	2	0	0	5	0.5
SSC	1	1	0	0	2	0.2
ASR	0	0	2	2	4	0.4
FCF	3	1	2	2	8	0.8
LOG	2	1	2	6	11	1.1
Other sub-total	16	12	13	17	58	5.8
Disqualified from strike	11	10	4	17	42	4.3
Total	248	218	230	279	975	100

a. Missions are: air interdiction (AI), close air support (CAS), interdiction (INT), offensive counter-air (OCA), suppression of enemy air defenses (SEAD), electronic support (ES), mission tanking (MTNK), tactical air reconnaissance pod system (TARPS), airborne early warning (AEW), defensive counter-air (DCA), surface search and coordination (SSC), armed surface reconnaissance (ASR), functional check flight (FCF), and logistics (LOG).

b. These are sorties dedicated solely to DCA missions. A combat air patrol (CAP) grid was maintained throughout the Surge. Some strike/fighters on their return from a strike mission would man the CAP stations. On several occasions, these aircraft were opposed by enemy aircraft. Because the strike/fighters' primary mission was delivery of air-to-ground ordnance, these sorties were counted in the strike category.

MAAP. Fleet operators cited another factor for this increase: because operators knew when the Surge would be completed, they pushed themselves and their systems to the limit. The knowledge of when operations are to end is not unique to exercises—in many real-world situations, fleet operators would know when an operational pause was possible.

Forty-two times during the Surge, aircraft launched on strike missions but did not meet NSAWC's criteria for strike sorties for several reasons: twenty-one sorties experienced air aborts (ten F-14s, nine F/A-18s, and two EA-6Bs); nineteen sorties in which aircraft intended to carry air-to-ground ordnance were launched without weapons (two F-14s and seventeen F/A-18s); and two F/A-18 sorties were redirected to DCA missions and did not go to the target area.

Table 5 shows the breakout of sorties flown by aircraft type. All CODs operated from the beach. Strike/fighter sorties in the "Other" category conducted DCA operations five times, one SSC mission, FCF flights seven times, and one logistics flight. In response to emerging scenario developments and at the request of his warfare commanders, Commander, Carrier Group Seven (acting as NAVFOR) several times redirected airborne aircraft intended for strike missions to conduct DCA and SSC operations. These actions reflect potential real-world requirements and serve as examples of an airwing's flexibility to respond to emerging tasking.

Table 5. Sorties flown by aircraft type and mission

Aircraft type	Strike	Strike support	Other	Disqualified from strike	Total	Average flight time (hours)
F-14A	118	9	6	12	145	2.1
F/A-18C	607	-	8	28	643	1.8
EA-6B	44	-	1	2	47	2.4
S-3B	2	83	5	-	90	2.2
ES-3A	-	12	-	-	12	4.5
E-2C	-	-	28	-	28	4.0
C-2	-	-	10	-	10	No data
Total	771	104	58	42	975	

Weapons expended

For virtually all strike/fighters, the weapons loadout was two live or inert 500-pound or 1,000-pound bombs, plus AIM 9, CATM 9, or CATM 88 weapons. These loadouts were chosen to be in accordance with those recommended in [3], restrictions imposed by the target complexes in the Southern California operating area (an exercise artificiality), and weapons bring-back restrictions.[2]

The servicing tasks were comparable to those required in a real-world scenario. The air-to-air weapons loadout for strike/fighters included two CATM 9s. The CATM 9 training missiles, like the AIM 9M, were armed and de-armed for each sortie. In addition, the nitrogen bottle in the CATM 9 (and the AIM 9M) was reloaded after every two sorties.

Figure 9 shows a breakdown of the strike sorties that delivered ordnance. Of the 771 strike sorties, forty-four were EA-6B Electronic Support (ES) sorties. The other 727 were loaded with bombs. All but two of these aircraft were configured with two Mk 80-series bombs: one F-14 carried four CBUs and one F/A-18 was loaded with only one Mk 80-series bomb. Six hundred eighty-three of the 727 bomb-laden aircraft scored target attacks: F-14s scored ninety-eight attacks, F/A-18s scored 583, and S-3s scored two attacks. Forty-four of the 727 bomb-laden aircraft did not attack targets for the reasons shown in the figure. These aircraft returned eighty bombs to USS *Nimitz* and jettisoned eight.

As shown in table 6, records kept by the *Nimitz* Ordnance Handling Officer (OHO) showed that a total of 1,336 bombs were dropped by CVW-9 aircraft during the Surge.

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2. An F/A-18 with two drop tanks, a targeting FLIR, air-to-air weapons, and three thousand pounds of JP-5 can recover with two 1,000-lb weapons and remain under its maximum trap weight for day and night operations, precluding the need to jettison ordnance brought back to USS *Nimitz*.

Figure 9. Breakdown of strike sorties

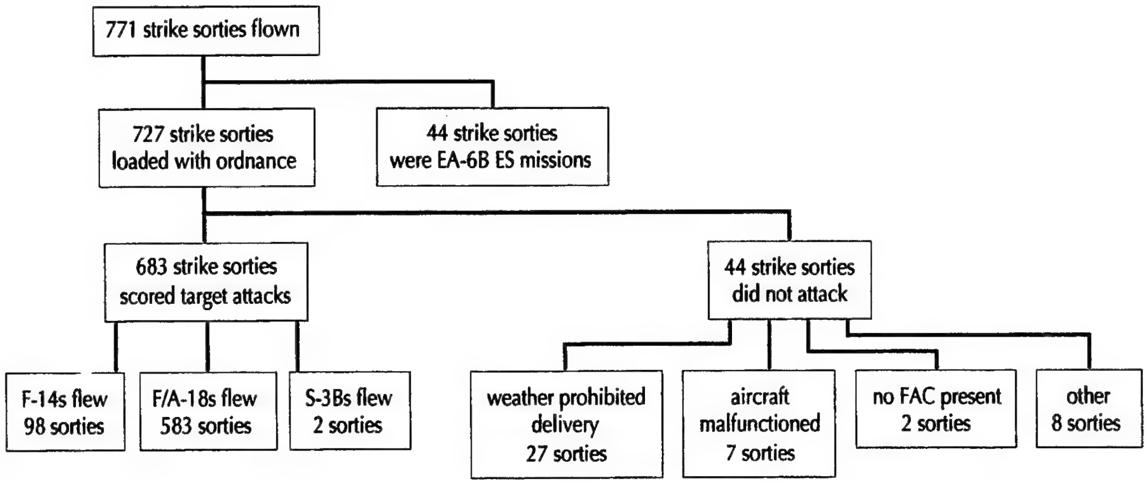


Table 6. Weapons dropped (based on *Nimitz* OHO records[a])

Weapon	Number dropped
BDU 45	765
Mk 82 GP	153
Mk 83 Inert	265
Mk 83 GP	148
Mk 20 Rockeye	5
Total	1,336

a. See appendix C (Volume 2).

Aircrew debriefs show that, for a variety of reasons, twenty-seven of the 683 aircraft dropped one bomb or none; see table 7. These twenty-seven sorties were credited with a target attack either because the target was closed (exercise artificiality) or because at least one bomb was dropped on the target.

Table 7. Sorties credited with target attacks (based on aircrew debriefs)

Number of sorties	Bombs dropped [a]	Bombs brought back	Remark
656	1,312	0	Attached target with two bombs
8	4	12	Exercise artificiality (range closed or planned bring back)
5	5	5	One hung bomb or aircraft malfunction
1	1	0	Loaded with only one bomb
12	10	14	Reason unknown
1	3	1	F-14 configured with Rockeye

a. The aircrew debriefs report the number of bombs dropped as 1,335, which does not match the records of the *Nimitz* OHO. The difference between the aircrew debriefs and the OHO's records cannot be reconciled with the data at hand.

Targets attacked

Carrier Airwing Nine strike aircraft attacked targets in four target complexes in the Southern California Operating Area: San Clemente Island (SCI); Camp Pendleton; the Chocolate Mountains; and Twenty-Nine Palms. Table 8 shows the number of sorties that delivered weapons to these targets.

Table 8. Strike sorties by target complex

Target complex	Day 1	Day 2	Day 3	Day 4	Total
Chocolate Mountains	46	41	28	53	168
Twenty-nine Palms	7	0	5	4	16
Pendleton	34	56	21	24	135
San Clemete Island	64	44	97	96	301
Other/unknown	27	16	34	30	107
Total	167	146	175	195	727[a]

a. The forty-four strike sorties that did not attack targets are not included.

The Chocolate Mountains and Twenty-Nine Palms target complexes were the most distant from USS *Nimitz* (between 170 and 280 n.mi. throughout the Surge) and provided opportunities to conduct medium-range strikes. These strikes were executed in response to the

need to maintain battlespace dominance, while the shorter range strike missions provided continued support to the amphibious forces ashore.

Table 9 shows the number of strike missions flown to targets, grouped by distance from USS *Nimitz*. These distances are not indicative of the maximum striking range of CVW-9 aircraft. Rather the distances were driven by the proximity of the carrier operating area relative to the Southern California target ranges. During the Surge, aircraft were frequently held overhead USS *Nimitz* awaiting recovery, time that in a real operation would have been spent transiting to and from more distant targets. Figure 10 shows the maximum operational strike range that could have been reached on each strike sortie.[3]

Table 9. Number of strike sorties by target distance from USS *Nimitz*

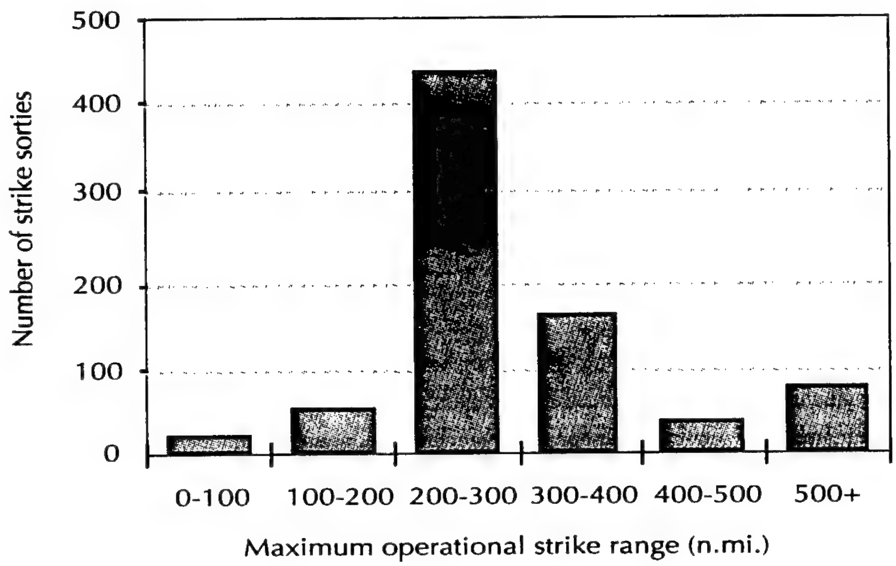
	Number of sorties		
Distance to target (n.mi.)	Strike	Strike support	Total
0 - 100	495	58	553
100 - 200	174	40	214
200+	58	6	64

During the four days of the Surge, weather in the target areas adversely affected strike operations. Coastal targets in Camp Pendleton and SCI target complexes were often obscured by a broken or overcast cloud layer, requiring strike aircraft to roll to other target areas (including the more distant Chocolate Mountains complex) or to return to USS *Nimitz*. Thunderstorms in the Chocolate Mountains

3. We based this computation on the aircraft flight times and on the requirement for aircraft to be in the Marshall pattern at the beginning of the recovery. We also accounted for the time required to engage, receive fuel, and disengage from tankers when refueling was necessary. We estimated the time for strike aircraft to locate the target as ten minutes [4]. We included a requirement to return to force on a seventy-five nautical mile dogleg (such a requirement was imposed during Operation Desert Storm).

complex interfered occasionally with strike execution, which caused a few strike aircraft to bring ordnance back to USS *Nimitz*.

Figure 10. Maximum operational strike ranges



SEAD support

Carrier Airwing Nine also employed on-call SEAD to support littoral strike missions. For these missions, the EA-6B was held on station, ready to support a number of concurrent strike packages should the need arise. For the medium-range strike missions intended to maintain battlespace dominance, each strike package had dedicated EA-6B SEAD support.

Tanking support

KC-135s and KC-130s were scheduled to be on station continuously. On one occasion, CVW-9 S-3B aircraft provided the tanking support to a strike to the Chocolate Mountains range when the inorganic tanker aircraft did not make its scheduled sortie. Carrier Airwing

Nine S-3s conducted recovery tanking and supplied over one-third of the fuel passed to CVW-9 aircraft during the Surge.

Ship aviation system support

Critical ship's aviation support systems (catapults, arresting gear, elevators, and radars) had little effect on the ability of USS *Nimitz* and CVW-9 to meet their sortie requirements. Most scheduled maintenance of these systems was scheduled around the Surge period, and thus did not impact flight operations. Two catapults were briefly down as a cycle was beginning to launch. Although this complicated operations on the flight deck, no sorties were missed and the recovery was not delayed.

Airframe utilization

Observed aircraft utility rates

Many factors influence the observed utility of aircraft, the most fundamental of which is the operational requirement. Different scenarios will demand different aircraft utilization rates; the observed utilization rate will be on a level at or below that set by the operational requirement. If a specific aircraft type is not used to its fullest capacity in one situation, this does not mean that those aircraft are surplus to the airwing. In other operational scenarios, those aircraft may be in high demand.

Table 10 shows the aircraft utility rates during the Surge and, for comparison, those of the 1995 *Roosevelt* Surge [5], the 1995 *Nimitz* Surge [6], and the Navy's (OPNAV N88) planning factors [7].[4] Except for the ES-3A, the utilization rates for the 1997 *Nimitz* Surge are greater than both the CNO (N88) planning factors and the 1995 *Roosevelt* Surge and are comparable to the two-day *Nimitz* Surge of 1995.

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4. The Navy's (OPNAV N88) planning factors are used in procurement and operational inventory assessments.

Table 10. Aircraft utility rates (sorties per aircraft per day)

Aircraft	*Nimitz* 1997 Surge	*Roosevelt* 1995 Surge[a]	*Nimitz* 1995 Surge[b]	CNO (N88) planning factors
F-14	2.6	1.9	2.2	2.0
F/A-18	4.5	2.4	4.7	2.0
EA-6B	2.9	1.8	1.8	1.9
S-3B	2.8	1.5	1.8	1.7
ES-3A	1.5	2.5	2.5	2.1
E-2C	1.8	1.5	1.8	1.7
C-2	1.1	not reported	not reported	not reported

a. The USS *Roosevelt* data were taken during a fifteen-hour-a-day four-day Surge that did not include ordnance expenditure.

b. The scenario for the 1995 *Nimitz* Surge called for support of forces in the littoral, but lasted only two days. Operations were conducted for nineteen hours the first day and twenty-four hours the second.

Figure 11 shows the distribution of F-14 sorties among F-14 airframes. The chart shows the number of aircraft that flew zero, one, two, etc., sorties. For example, the chart shows that two F-14s did not fly during the Surge. The next bar indicates that two other aircraft each flew four sorties. One F-14 flew eighteen sorties, shown by the bar at the far right-hand corner. Also indicated in the figure is the expected distribution of sorties among airframes based on simulation modeling [8, 9]. For this simulation, we used the Surge MAAP (to specify the operational requirement) and an extensive database of fleet aircraft maintenance data (to estimate airframe usage). The simulation is a *Monte Carlo* routine and as such, the values plotted in figure 11 indicate average or expected values.

Figure 12 is the overall utilization of the F/A-18 airframes. You will note that one airframe flew thirty times during the four-day Surge. While this was not typical of all airframes, it does show the potential of the F/A-18. The results of our simulation modeling are superimposed on the operational data. As before, there appears to be a good match between the modeling results and the observed performance.

Figure 11. F-14 airframe utilization

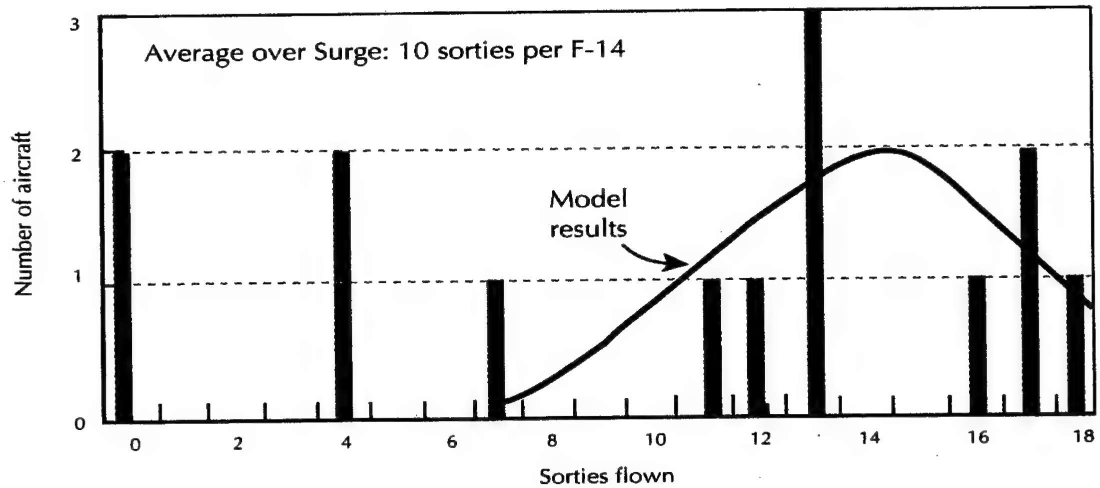
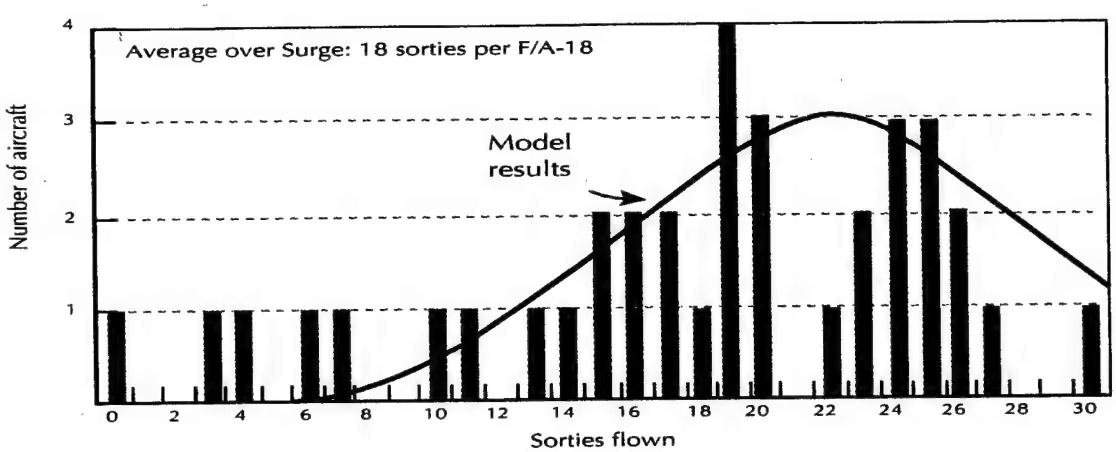


Figure 12. F/A-18 airframe utilization[a]

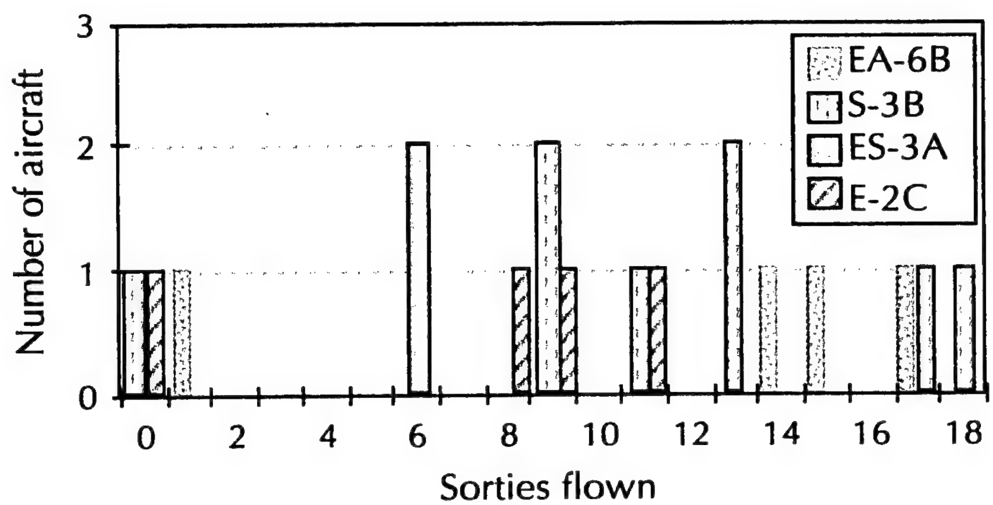


a. The total sorties shown is 642, one less than the total reported in table 5. We did not count one sortie—an F/A-18D—that flew from the beach and launched off USS *Nimitz* toward the CVW-9 F/A-18 utility rate.

The models we used historically have shown a good agreement with fleet performance under a variety of operational requirements and scenarios. The agreement we observed between the model's predictions and the *Nimitz* Surge data indicates that what was demonstrated by USS *Nimitz* was not a fluke. Rather, similar performance should be attainable by other carrier battle groups (under similar operational requirements).

For completeness, figure 13 presents the airframe utilization for the EA-6B, S-3B, ES-3A, and E-2. Forty-six of the forty-seven VAQ sorties were generated by three aircraft. The VAW squadron essentially operated with only three aircraft. The mission requirement for virtually continual airborne presence by the EA-6B and ES-3 meant these aircraft were frequently tanked and kept airborne for extended periods of time; table 8, you will recall, showed an average flight time of 2.4 and 4.5 hours for the EA-6B and ES-3, respectively. Thus, the number of sorties they generated is not an adequate measure of their contribution to the Surge effort.

Figure 13. EA-6B, S-3B, ES-3A, and E-2 airframe utilization



Sparing concepts

An airwing schedules spare aircraft as insurance that a sortie will fly.[5] If the primary aircraft goes down or if flight deck crews cannot ready sufficient numbers of aircraft in time for the launch, the spare can be launched instead. In a joint operation, when the flight operating tempo is regulated by an air tasking order (ATO), the CV/CVW does not have the luxury of delaying the launch of some strike aircraft until they are ready to fly. Sparing in a joint operation can be critical to achieving mission objectives. During the Surge, fifty-three strike/fighters went down before launch and the flight deck crews were unable to ready an additional nine strike/fighters in time for the next launch. Thirty-six spares were manned during the Surge, under three different sparing concepts.

With the *conventional* sparing concept the squadron provides an extra aircraft to spare for only its own aircraft. The spare is manned by a pilot who has been briefed on the missions for which he is sparing. The aircraft is loaded with weapons that are consistent with the mission for which it could be called to execute. As long as the mission requirements remain the same, a readied spare aircraft can spare for several events (until it is needed). There are costs associated with the conventional sparing concept: the workload of the flight deck crews is increased commensurate with the number of spares; and aircrew utilization is increased because each spare requires an additional aircrew man-up. Sparing also complicates flight deck activities because spares must be spotted in locations that allow them to be quickly inserted in the launch sequence. During the Surge, conventional spares were manned thirty-one times and flown seven times.

With the *Super Spare* concept a spare need not be drawn from the same squadron as the down aircraft. For example, an F-14 could spare for another F-14 or for an F/A-18, provided the mission was the same. In essence, Super Spare is a means of pooling assets between squadrons. As with conventional spares, the Super Spare pilot attends

5. Spares can also provide a resource to respond to emergent tasking, which happened twice during the Surge.

mission briefings and the aircraft is loaded with the appropriate weapons.

The nature of strike operations during the Surge lent itself to use of the Super Spare concept. The standardization of strike tactics by NSAWC allowed aircrews to be briefed on planned execution of a specific strike in the cockpit. All strike/fighter aircraft carried virtually the same weapons loadout, so unused Super Spare aircraft did not have to be reconfigured from one launch to the next. This eased the demands on the ordnance crews. Indeed, ready aircraft intended for launch on later events could be used to Super Spare the current event. During the Surge, the F/A-18 was the aircraft of choice for Super Spare missions. This was due in part to a realization by the airwing that the F-14s were less reliable than the F/A-18s. According to the air plan and the cat/trap log, Super Spares (all F/A-18s) were scheduled for only four events, all on 21 July.

With the *Get In and Go* (GIGO) sparing concept an aircraft is readied, but not manned. If an aircraft goes down before launch, the aircrew moves to the GIGO spare aircraft and makes the launch. Because no additional aircrew is required for the spare aircraft, the GIGO sparing concept does not increase the pilot utility rate. In addition, it does not require additional servicing of the aircraft because the spare's avionics and engines are not turned on unless needed. Aviators estimate the cut-off time, beyond which it would be impossible for the aircrew to relocate to the GIGO spare, to be between twelve and sixteen minutes before the end of the event launch. During the Surge, the *Nimitz* Commanding Officer was the arbiter on a case-by-case basis as to whether sufficient time was available to implement the GIGO spare. We know of only one instance in which the GIGO spare was manned during the Surge.

Spares were scheduled for half the Surge events. Table 11 summarizes the use of spares in the Surge. Of the thirty-six spares manned, eight flew—six for aircraft that went down and two that launched in response to requests for immediate support from ground-based forward air controllers (FACs). In all but one instance, aircraft spared for aircraft of the same type. Five of the twenty-seven unused spares were NMC at launch time; the remaining twenty-two were MC and

available for tasking. For these twenty-two, seven opportunities for sparing were lost during the Surge. In every case, these were F-14s manned as conventional spares when F/A-18s went down or when time was not sufficient to complete F/A-18 arming. Discovery that the F/A-18s were down was in time to substitute with the F-14 spares. Had all spares been Super Spares, seven additional strike sorties could have flown without increasing pilot utility rates.

On twenty-three events for which no spares were scheduled, strike/fighters went down or ordnance crews were unable to complete arming aircraft in time for launch. But in all cases, sufficient time remained to substitute a spare aircraft. Had spares been manned and used on all events, this would have presented opportunities for generating additional strike/fighter sorties. The cost for doing this would have been to raise the average pilot utilization rate by 0.1.

During the Surge, USS *Nimitz* and CVW-9 generated 771 strike sorties. Adding the seven sorties lost to events that were spared and the twenty-three sorties lost to events that were not spared gives the potential for 801 strike sorties. The bottom line: with a more aggressive use of sparing, USS *Nimitz* and CVW-9 could have generated 801 strike sorties.

Table 11. Use of spares

Date	Aircraft and mission[a]	Did it fly?	Could have spared for these aircraft	Comments
20 July (six spares manned)	F-14 (OCA)	Yes, for F-14 (OCA)	-	
	F-14 (AI/DCA)	No	-	
	F-14 (OCA)	Yes, for F-14 (AI/DCA)	-	
	F-14 (AI)	No	-	
	F-14 (OCA)	Yes, for F-14 (OCA)	-	
	F-14 (AI)	No	-	
21 July (eleven spares manned)	F-14 (OCA)	No	F/A-18 (AI/DCA)	Lost opportunity
	F/A-18 (INT)	Yes, for F/A-18 (INT)	-	Super spare
	F-14 (AI)	Yes, for F-14 (AI)	F/A-18 (no bombs)	
	F/A-18 (INT)	No	F-14 (AI/DCA) F-14 (OCA)	NMC Super spare
	F-14 (AI/DCA)	No	-	
	F-14 (AI)	Yes, for no one	-	FAC request
	F-14 (OCA)	No	-	
	F/A-18 (INT)	No	-	Super spare
	F-14 (AI)	No	F/A-18 (AI) F/A-18 (no bombs)	Lost opportunity
	F-14 (OCA)	No	-	
	F/A-18 (INT)	No	-	Super spare
22 July (six spares manned)	F-14 (CAS)	No	-	
	F-14 (AI)	No	F/A-18 (CAS)	Lost opportunity
	F-14 (AI)	No	F/A-18 (AI) F/A-18 (CAS)	NMC
	F-14 (CAS)	No	F/A-18 (AI)	Lost opportunity
	F-14 (AI)	No	-	
	F-14 (AI)	No	-	
23 July (nine spares manned)	F-14 (OCA)	No	-	
	F-14 (AI/ASR)	No	-	
	F-14 (AI/ASR)	No	F-14 (AI/ASR) F/A-18 (AI/ASR)	NMC
	F-14 (CAS)	Yes, for no one	-	FAC request
	F-14 (AI)	No	F/A-18 (CAS)	Lost opportunity
	F-14 (AI)	No	F-14 (AI)	NMC
	F-14 (AI)	No	F/A-18 (CAS)	NMC
	F-14 (AI)	No	-	
	F-14 (AI)	No	F/A-18 (no bombs)	Lost opportunity
July 24 (three spares manned)	F-14 (AI)	No	-	
	F-14 (AI)	No	F/A-18 (CAS) F-14 (no bombs)	Lost opportunity
	F-14 (CAS)	Yes, for F/A-18 (CAS)	-	

a. Missions are offensive counter-air (OCA), air interdiction (AI), defensive counter-air (DCA), interdiction (INT), close air support (CAS), and armed surveillance reconnaissance (ASR).

Aircrew utilization

Carrier Airwing Nine was augmented with additional strike/fighter pilots, increasing the number of F-14 pilots from twenty to twenty-two, and the number of F/A-18 pilots from fifty-eight[6] to seventy-nine. (In addition, some members of the Carrier Group Seven staff, ship's company, and the CVW staff were qualified to fly tactical aircraft. These pilots did fly (although not at the rates typical of squadron pilots) and would be available for combat missions should the real-world need arise.)

Not all pilots will be available for flight duty at all times—some will be on medical flight status, others will be performing liaison officer duties or standing watch. Previous studies have used a nominal value of ten percent of the squadron's aircrew lost to these other duties. By command direction, non-flying duties were kept to a minimum—for example, pri-fly watches were consolidated among the F/A-18 squadrons.

Strike leader tasking was eased by the inclusion of the Operational Strike Planning Cell (OSPC). The OSPC planned interdiction missions from launch to IP, conducted targeteering, prepared strike mission packages for the strikes, coordinated the tanking plans, briefed the strike leaders on the missions, and coordinated the administrative functions supporting air interdiction and close air support execution. They also served as a bomb damage assessment (BDA) cell. The OSPC removed a major workload from the aircrew, maintained planning standardization and continuity, and coordinated the strike campaign with the JFACC and JAOC.

A pilot utility rate is the average number of times a pilot mans an aircraft per day, for whatever reason. The rate encompasses sorties flown, the times spare aircraft were manned, and the times a manned aircraft went down before launch.

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6. Carrier Airwing Nine complement was twenty pilots each for two F/A-18 squadrons and eighteen pilots for the third F/A-18 squadron.

To determine the number of squadron man-ups, we tallied the number of F-14 and F/A-18 sorties flown,[7] the number of spares that were manned but did not fly, and the number of manned aircraft that went down before launch. Then we subtracted those sorties flown by pilots not attached to squadrons in the airwing (primarily CVW staff). We calculated that F-14 aircrews manned aircraft 183 times, and that F/A-18 pilots manned their aircraft 660 times.

With the number of man-ups the airwing achieved during Surge, we calculated the pilot utility rate, shown in table 12. At the outset of the Surge, Commander, Carrier Group Seven capped pilot utilization rates at 2.5; note that during the Surge the airwing approached but never exceeded this goal.

Table 12. Pilot utilization

	Pilots		Man-ups over the four-day Surge[a]	Pilot utilization (man-ups/day/aircrew)				
Aircraft	CVW-9 complement	Augmentation		Surge average	Day 1	Day 2	Day 3	Day 4
F-14A	20[b]	2	183	2.1	1.9	1.9	1.8	2.6
F/A-18C	58[c]	21	660	2.1	2.2	1.9	1.9	2.3
EA-6B	7	0	48	1.7	1.7	1.6	1.7	1.9
S-3B	12	0	84	1.8	1.8	1.5	1.8	2.0
ES-3A	4	0	17	0.9	1.2	1.0	0.8	0.8
E-2C	6[d]	0	28	1.1	1.1	1.1	1.1	1.1

a. Includes only those man-ups made by augmentees or squadron pilots.
b. Deployment complement of 17.
c. Deployment complement of 51.
d. Mission commanders.

Figures 14 and 15 display the distribution of aircrew utilization data for pilots of each aircraft type. During the Surge, we found that all squadron strike/fighter pilots (including the augmentees) flew or manned aircraft at least three times.

7. We counted all sorties regardless of whether they qualified as strike sorties.

Figure 14. Distribution of F/A-18 and F-14 pilot utilization rates

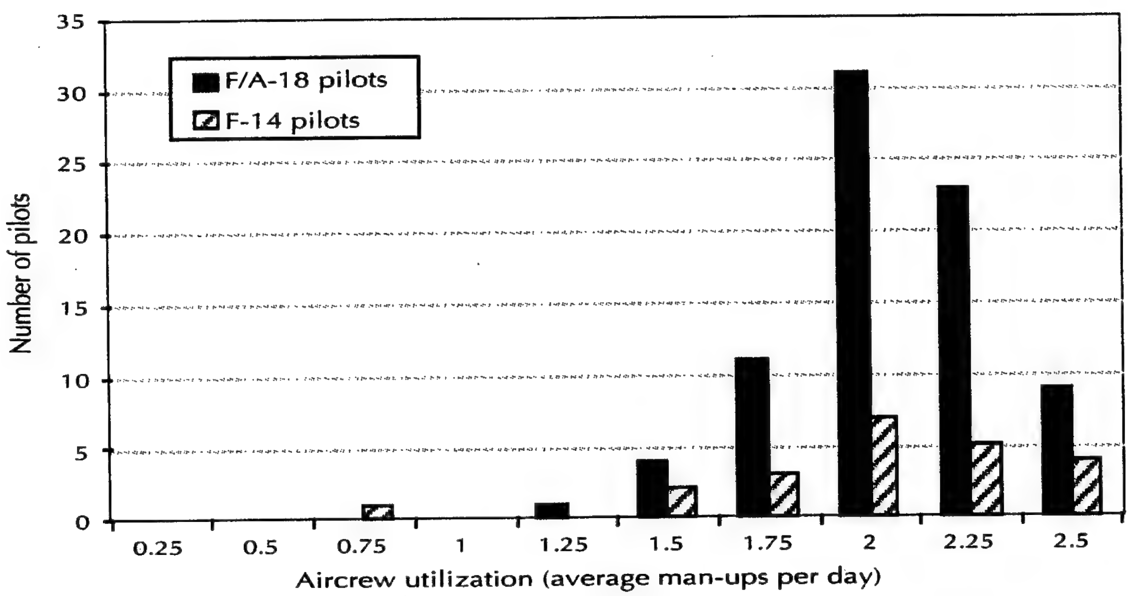
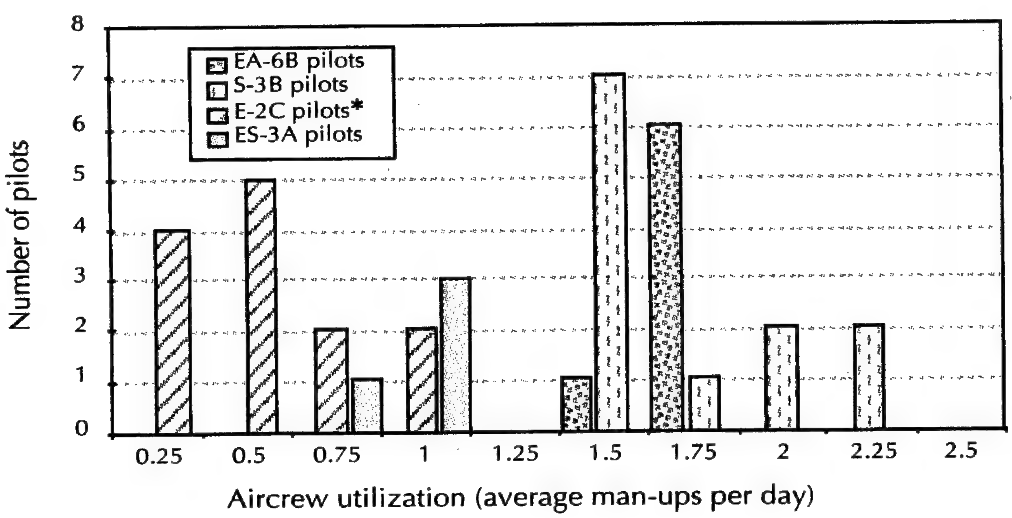


Figure 15. Distribution of pilot utilization rates (EA-6B, S-3B, E-2C, ES-3A)



* *Thirteen pilots on board, six of which were mission commanders.*

Flight and hangar deck employment

Flight deck density

Operational experience has shown that configuring the flight deck with more than eighty percent of its maximum loading usually results in crowding and actually inhibits sortie generation. For USS *Nimitz*, this is equivalent to restricting the number of aircraft on the flight deck to sixty-four F/A-18 deck spots. To keep the flight deck density within workable tolerances during the Surge, MC aircraft frequently were kept in the hangar bay and, on some occasions, MC aircraft were transferred from the flight deck to the hangar deck.

USS *Nimitz* started the Surge on 20 July with eighteen fixed-wing aircraft in the hangar bay and fifty on the flight deck. The working goal of USS *Nimitz* and CVW-9 was to have no more than nine strike/fighter aircraft from each squadron on the flight deck or in the air at any one time. After the first launch, the flight deck crews generally managed the number of aircraft with ease. Difficulties arose when the number of aircraft on the flight deck rose. (This occurred each night between 0300 and 0500 when the operating tempo was reduced to decrease the operational risk to aircrew.[8]) Over time the average number of fixed-wing aircraft on the flight deck outside these early morning hours was twenty-seven, with eighteen aircraft airborne. In contrast, during the early morning periods the number of aircraft on the flight deck averaged thirty-two with thirteen airborne. The number of aircraft on the flight deck throughout the Surge averaged twenty-eight with between seventeen and eighteen aircraft airborne. Table 13 summarizes the statistics on the loading of the flight deck. Note that after the first launch USS *Nimitz* and CVW-9 kept the deck loading below eighty percent throughout the Surge. However, in comparison to previous Surge exercises [5, 7], USS *Nimitz* operated with a fuller flight deck.

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8. The research conducted by USS *Nimitz* and CVW-9 on the latest physiological assessment of human fatigue identified 0300 to 0500 as a period of reduced mental and physical capabilities. In response, the *Nimitz* MAAP was revised to ease pilot task loading during this period.

Table 13. Number of fixed-wing aircraft on flight deck

	Number of aircraft on flight deck				Percent of max loading[a]
	Average	Median	Maximum	Minimum	Average
Day 1	30	31	50	15	58
Day 2	33	34	42	14	62
Day 3	26	26	35	12	52
Day 4	22	24	31	5	46
Surge overall	28	28	50[b]	5[c]	55
Day 1 - early AM	35	35	38	25	63
Day 2 - early AM	37	38	39	29	67
Day 3 - early AM	31	31	35	23	57
Day 4 - early AM	27	26	31	18	53

a. In this calculation, we reserved space for three helicopters and included an overhead allowance of ten spots occupied by GSE and consumables. C-2s are included in the calculation.

b. Occurred before the first event launched.

c. Occurred after the last launch, when all MC aircraft on the flight deck were launched.

After the first two days, USS *Nimitz* and CVW-9 intentionally reduced the number of aircraft on the flight deck to ease turnaround operations. This reduction can be seen in figure 16, which shows the fluctuations in the number of fixed-wing aircraft on the flight deck throughout the Surge. (C-2s were included in this calculation.) By the end of the Surge, fleet operators felt that the optimum number of aircraft on the flight deck was twenty-five (for a loading of fifty percent).

Operating tempo

Managing the flight deck means overseeing the readying of aircraft for launch and anticipating the needs of airborne aircraft. It is an intricate juggling of assets in which timing is everything. We discussed the number of aircraft on the flight deck and now we turn to the number of aircraft in the air and the rate at which aircraft changed their flying status.

Figure 16. Number of fixed-wing aircraft on the flight deck

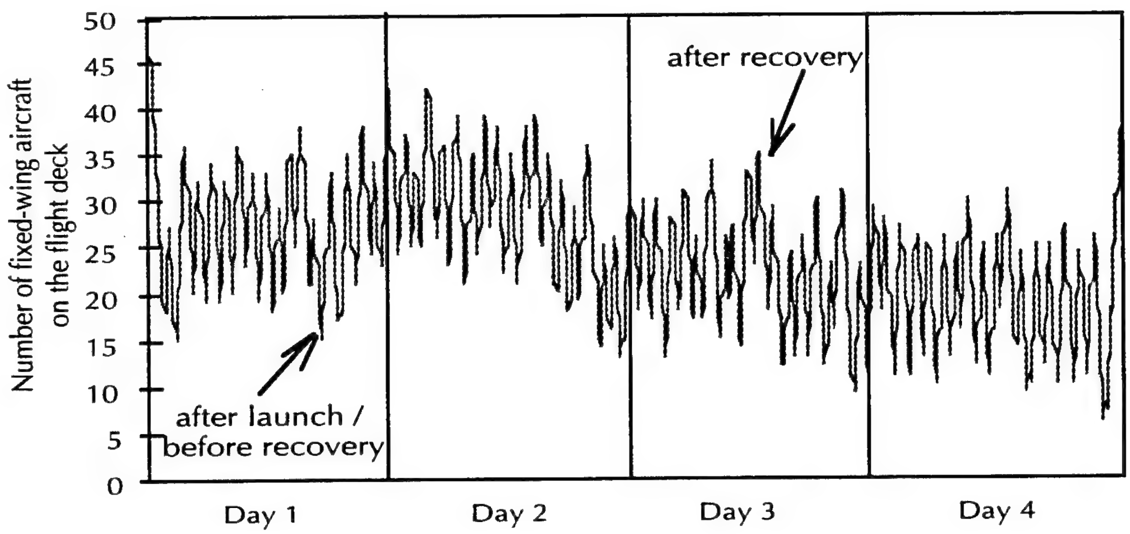
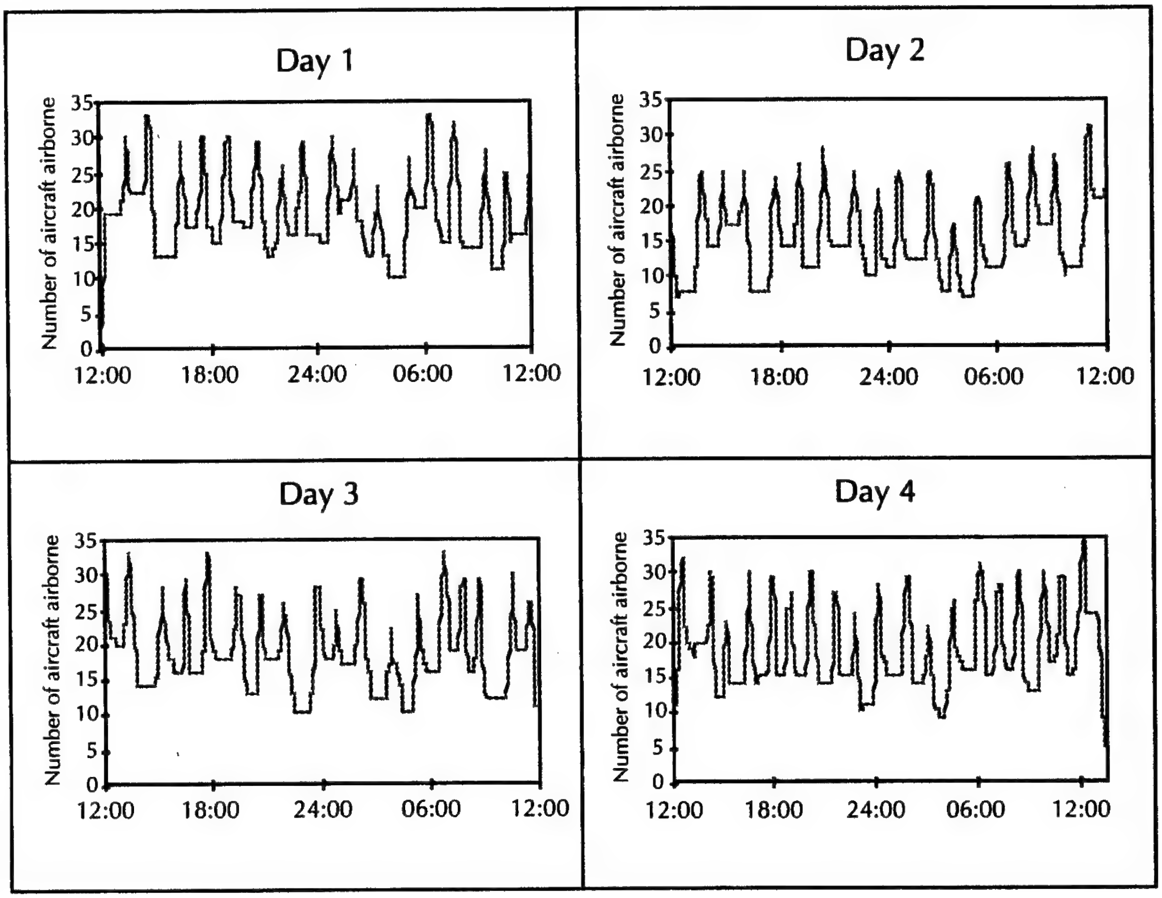


Figure 17 shows the number of aircraft airborne over the four days of Surge. The number remains relatively constant over the four days, but you will note the early morning dips we discussed earlier. On average USS *Nimitz* and CVW-9 kept between seventeen and eighteen aircraft airborne.

To meet the requirement for both high-intensity littoral operations and medium-range sustainment strikes, a baseline air plan was developed using a 1+15, 1+15, 1+45 cycle template, for day and night operations, transitioning to a 1+00, 1+00, 1+45 template during the final daylight missions. In practice, the 1+00 cycles proved exceptionally challenging, nearly forcing the flight deck into operating in a flex-deck mode.

Even the 1+15 cycles at times proved challenging. On six 1+15 cycles, a few aircraft had to be launched after the recovery began. This indicates the flight deck crews had insufficient time to turn aircraft around before the "must start" time of the recovery. During night operations, several factors reduce the time available for aircraft turnaround: recovery times are longer, aircraft and ordnance movement on the flight deck are slower, and boarding rates are decreased. These factors had the greatest effect during the 1+15 cycles.

Figure 17. Number of fixed-wing aircraft airborne[a]



a. The spikes in this figure occur during launches and recoveries. The number of aircraft airborne increases rapidly during a launch and falls with the recovery.

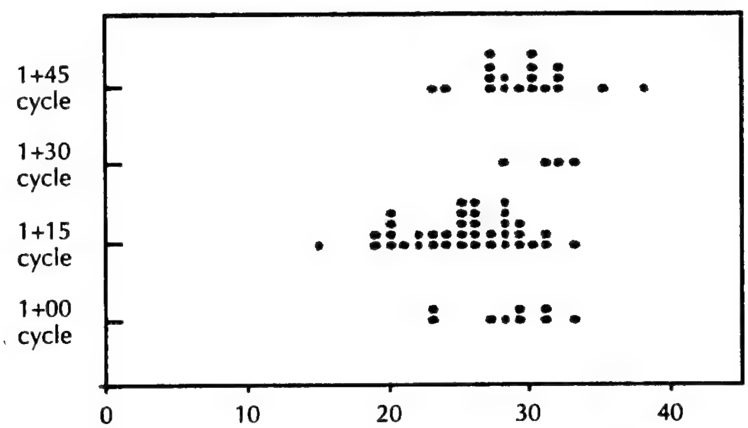
To be independent of tanking, F/A-18Cs must operate on cycles of 1+20 or shorter. At operating tempos comparable to the Surge, the cycle time must be between 1+15 and 1+20 unless non-organic tankers are available.

The 1+00 cycle appeared to increase the pressure on personnel significantly, which in turn seemed to exacerbate fatigue. While crews managed to ready their quota of aircraft in the first 1+00 cycle, the following 1+00 was too short and on three of the six attempts to change the cycle template, operators in real-time slid the template to

1+00, 1+15, 1+30. The overall assessment from operators was that under this operating tempo, the cycle time should be at least 1+15.

Figure 18 shows the distribution of the number of aircraft launched and recovered during each type of cycle. Fewer aircraft were launched and recovered during the 1+15 cycles than the others. The 1+00 cycle, interestingly, had about the same number of aircraft launch and recover as did the 1+45 cycle.

Figure 18. Operating tempo by cycle length



Extended recovery pattern

During the Surge, CVW-9 tested a new recovery pattern for Case I and Case II day conditions. The standard recovery pattern calls for a banked turn, initiated as the aircraft comes abeam of the carrier fantail, followed by a descending approach to the carrier ("*in the groove*"). As figure 19 shows, the new pattern extends the downwind leg by approximately three-quarters of a nautical mile and calls for a level turn followed by a descending approach to the carrier. The rate at which aircraft enter the break does not change, so the time interval between aircraft in the pattern should not be affected. But the slower rate of turn and the longer time in the groove (an additional fifteen

to eighteen seconds) was expected to facilitate a stable approach. In addition, the new pattern is safer because the turn to the final approach is more gradual, avoiding stalls or spin conditions. Indeed, CVW-9 anticipated a decrease in the rate of technique wave-offs and bolters.

The Surge bolter rate (the number of bolters divided by the number of approaches to carrier) is shown in figure 20. The average Surge bolter rate was 33 bolters per 1,000 approaches to the flight deck. For comparison, CVW-8's and CVW-2's bolter rates using the standard recovery pattern during daylight operations was 28 and 36 bolters per 1,000 approaches, respectively. The CVW-9 bolter rate fell between these two.

Figure 19. Extended day recovery pattern

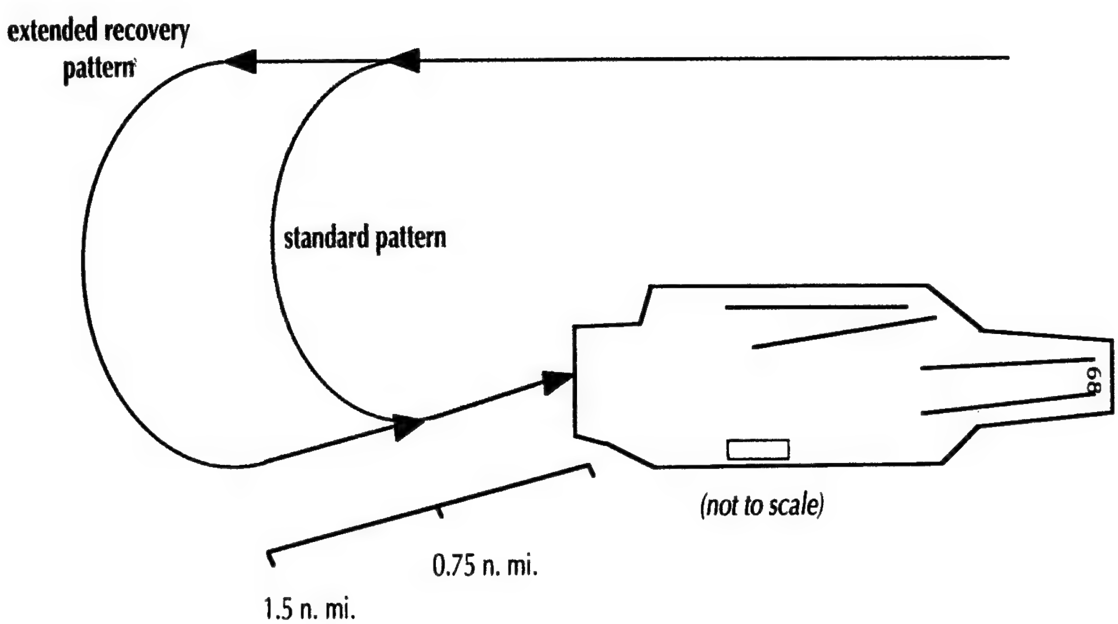


Figure 20. CVW-9 average bolter rates

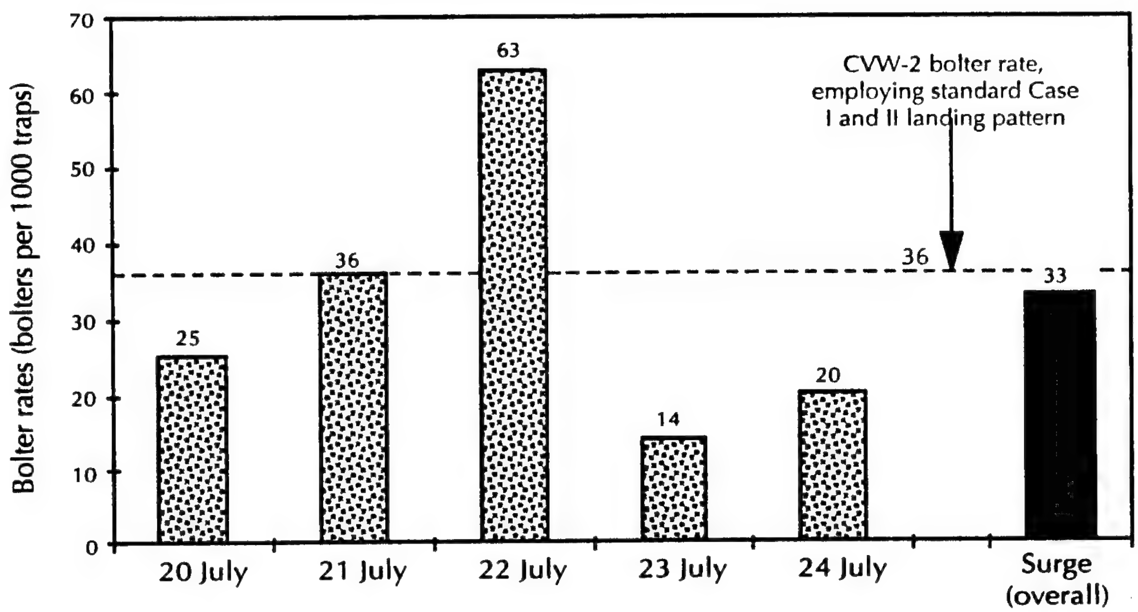
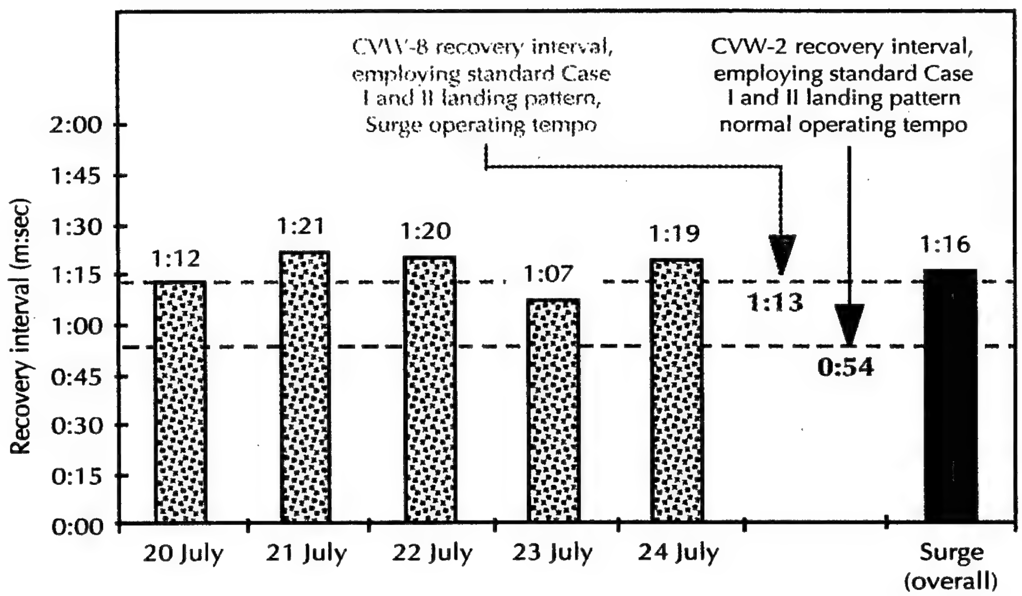


Figure 21 shows Surge recovery intervals. Aircraft recoveries are recorded to the minute, while recovery intervals are calculated to the second. As a result, the calculation of the recovery interval has uncertainly in it. However, this uncertainty in the calculated values shown in the figure is within five seconds.

The recovery interval targeted by CVW-9 was one minute; during the Surge, the recovery interval averaged 1:16 (with a median of 1:13). Daily performance varied from a low of 1:07 to a a high of 1:21. This compares well with the Case I recovery interval of 1:13 seen by CVW-8 in USS *Roosevelt*'s 1995 Surge, which used the standard recovery pattern [5]. Data taken during a recent cruise by CVW-2 conducting normal peacetime operations, averaged 0:54 for the recovery interval using the standard recovery pattern (Case I and Case II). Reference [10] also reports 0:57 as a typical recovery interval. The arresting wire reset time is thirty-seven seconds, which places a lower bound on the achievable aircraft recovery interval.

Figure 21. CVW-9 recovery intervals



Although the extended recovery pattern resulted in a lower bolter rate (over ten percent lower) than the CVW-2 cruise data, there was an increase in the average recovery interval. When compared to CVW-8's experience during high-intensity operations, the recovery intervals in the Surge were virtually identical. Keep in mind that events that extend recoveries (such as foul decks or bolters) will occur periodically. The larger the number of aircraft in a recovery, the more likely one of these events will happen within the recovery. As a result, the higher the operating tempo, the longer the average recovery interval.

There was at least one observed drawback to the extended recovery pattern. In contrast to the standard pattern, the new pattern relies on the pilot to set the interval between aircraft based on the distance to the preceding aircraft. Pilots commented that this is more challenging than the standard pattern's method of relying on visual cues based on the carrier.

The extended recovery pattern was new to the augmentee pilots and the resident CVW-9 pilots had trained with it only during work-ups. Practice with the extended recovery pattern may lower the recovery

interval and bolter rate in future operations. An on-going study, sponsored by Commander, Naval Air Pacific, is examining the experiences of several deployed airwings with the extended recovery pattern to determine whether proficiency improves with practice and whether the extended recovery pattern is more efficient than the standard pattern.

Ordnance issues

Weapons buildup process

The ordnance tasking was promulgated in a daily load plan for USS *Nimitz*. The process required a series of steps—breaking out the bombs from the shipping pallets, hoisting weapons onto a bomb table, and attaching fins using pneumatic tools. The weapons were then hoisted from the table onto bomb skids. The Mk 80-series weapons expended during the Surge are the simplest U.S. Navy air-to-ground ordnance to build. In other scenarios requiring employment of more technologically sophisticated weapons, the rate at which weapons could be readied may be significantly less than that seen in the Surge. The aviation ordnance personnel (AOs) pace the weapons buildup process to match the desired expenditure rate. If the rate at which weapons are built is too low, aircraft will not have ordnance to strike enemy targets; if the rate is too high, weapons will accumulate and congest the staging areas. During the Surge, the pace of the buildup of ordnance matched well to that of the expenditure rate.

During the Surge, ordnance buildup took place in both the forward and aft weapons magazines. The AOs worked as a team and the buildup rate increased throughout the Surge as a battle rhythm was achieved. Part of the team was responsible for loading the skids onto the elevators for movement up to the mess deck level. Movement out of the magazine was critical; if there was not a sufficient flow of weapons out of the magazine, the built-up weapons would consume the small amount of available space and construction of new bombs would halt.

Moving weapons and replacement parts to the flight deck

Moving weapons from the hangar deck to the flight deck proved to be the most difficult step in transporting weapons from the magazines to the awaiting aircraft. Weapons were almost always brought to the flight deck on the Number Two Elevator, just forward of the island, as this was the shortest path for moving weapons to the bomb farm. The use of this elevator required coordination with the aircraft handling officer and the ship's bridge. Although this coordination usually went smoothly, the heavy reliance on this aircraft elevator made ordnance movement vulnerable to interruption. On several occasions, sea state conditions, carrier turns, or flight deck operations prevented an elevator run in response to ordnance crews' first request.

USS *Nimitz*'s deck-edge elevators are rated to carry 130,000 pounds [11]. Table 14 shows the number of Mk 82 or Mk 83 bombs on skids that could be loaded on a deck-edge elevator along with no, one, or two F/A-18s. The weight capacity of the elevators and the items other than ordnance loaded on them did not constrain the amount of ordnance that could be moved from the hangar deck to the flight deck on the deck-edge elevators. Every Elevator Two move carried either ordnance or bomb skids (along with other items).

Table 14. Deck-edge elevators' weapons-carrying capacity[a]

Number F/A-18s on elevator[b]	Maximum number of bombs	
	Mk 82	Mk 83
0	240	120
1	160	80
2	70	35

a. Plane captains, tow bars, and chains add 500 pounds for each aircraft carried. Each Aero 21C bomb skid weighs 234 pounds with a capacity of 5,000 pounds, roughly five Mk 83s or ten Mk 82s.

b. F/A-18 configuration is two drop tanks and two Mk 83s. Allowing for a full fuel tank, this gives an F/A-18 weight of 45,000 pounds.

USS *Nimitz* has three weapons elevators: the forward bomb elevator, located between Catapults One and Two; an elevator aft of the bow catapult jet blast deflectors; and the elevator directly abeam of the island. Use of the weapons elevators is directed by the Handler. Why didn't the Handler authorize ordnance crews to use one of these dedicated weapons elevators? Each weapons elevator had costs associated with its use under high operating tempo conditions. The capacity of each of the weapons elevators is far less than that of a deck-edge elevator. For example, a weapons elevator can accommodate four skids with Mk 82s or two HARM skids. As a result, more runs (and more time) are required to transfer the same amount of ordnance. Further, the weapons elevators are located in high-use areas on the flight deck and use of a weapons elevator would have disrupted flight deck operations. In addition, the weapons elevator abeam the island cannot be used at night.

The CAG Gunner's goal was to always have enough weapons and replacement parts for two launches staged in the bomb farm located on the flight deck, outboard of the island. For the majority of the Surge this goal was met. Nitrogen bottles (installed in LAU 7 launchers for cooling AIM 9 missiles that had to be swapped out every two sorties) were also staged on the flight deck, but in limited quantities due to space availability. Only fourteen of these bottles could be stored on the flight deck at any one time due to space limitations. This inventory would be depleted within two cycles. A few times elevator runs were required specifically to transport additional nitrogen bottles to the flight deck.

Ordnance loading operations

A typical F/A-18 squadron will have different crews responsible for loading guns, air-to-air ordnance, and air-to-ground ordnance. During the Surge, however, all ordnance personnel worked together to load the aircraft with air-to-ground ordnance. The fifteen-man ordnance crews were organized in the following fashion:

- Ten ordnance loaders
- One safety observer
- Two CAD/fuzing personnel

- One to two personnel to assist as needed.

The time to load inert weapons was not significantly shorter than that for live ordnance. The only time savings came from not having to fuze weapons. Observations indicated fuzing required about four minutes per bomb. Because fuzing was conducted concurrent with other turn-around operations, the effect on sortie generation was minimal. Ordnance personnel felt that not fuzing all the weapons did not significantly reduce their fatigue.

Loading an aircraft

Configuring aircraft with weapons was executed concurrent with all other flight deck activities, including fueling the aircraft. Weapons could not be loaded on aircraft that were turning, not chained and chocked, or being jacked or having their tires filled with nitrogen. We observed the general order to loading ordnance on aircraft:

- Aircraft recovered and taxied to the de-arming area.
- Air-to-air weapons were de-armed.
- Aircraft taxied to spot (F/A-18s typically were spotted on the bow).
- Ordnance crews moved bombs from bomb farm to aircraft as it reached its final spot.
- Aircraft were shut down and secured.
- Spent CADS were removed from the bomb racks.
- Bombs were positioned under the racks on skids and hoisted into position. During the Surge, all bombs were loaded manually; typically, ten ordnance personnel were needed to lift 1,000-pound bombs to the racks. If 2,000-pound bombs had been used, a powered hoist would have been required.
- The ordnance crew moved to load the next bomb while an arming crew remained to install the arming wire on the first bomb.
- Once all bombs were loaded and armed, a quality assurance inspection was completed by the ordnance crew.

Ideally, all these tasks should be completed before the pilot mans the aircraft. During the Surge, however, pilots were often already in the cockpit while ordnance crews were still loading weapons.

The activities listed above take place concurrently with other turnaround tasks. Simultaneous fueling and weapons loading is authorized by CV NATOPS [12], which states that "simultaneous fueling, loading, and downloading of weapons, preloaded MERS/TERS, and installation of fuzes and arming wires *is authorized*." However, CV NATOPS states that

> loading of forward firing ordnance requiring simultaneous and/or prior electrical connections for loading *is not authorized* while fueling of that aircraft is in progress. No other electrical connections to weapons or removal/installation of impulse cartridge shall be accomplished while fueling of the aircraft is in progress. Fuel hoses shall not be positioned under weapons being loaded/downloaded. [Emphasis added.]

This requirement affected only the integration of bomb fuzing and CAD removal/replacement with aircraft fueling. The ordnance-loading crews and fueling crews coordinated their actions to meet this requirement. Often a fueling crew would briefly postpone (by two to three minutes) the start of fueling to allow ordnance personnel to remove spent CADS from an aircraft. After this short delay, the weapons loading proceeded in parallel with fueling.

After five uses, bomb racks require cleaning. Removing the racks is a time-consuming process. Instead of immediately removing and cleaning soiled racks, ordnance crews would leave them in place and use the other set of ordnance stations, extending the line duty of each strike/fighter aircraft. Concern for the readiness of the weapons racks caused five F-14 missions to be tasked with expending only a single weapon on each mission. These instances occurred at a time when few F-14s were mission-capable; by husbanding the use of the bomb racks, the use of these F-14s was extended. When all four racks required cleaning (typically after ten sorties), the aircraft would be taken off line and the four racks replaced simultaneously. This extension of the on-line time of strike/fighter aircraft would not be possible in scenarios requiring weapons loads greater then two bombs. In

these situations, more time would have been required to ready aircraft for launch, and sortie generation would have been reduced.

Loading a strike package

We observed flight deck crews ready aircraft for launch. Once a battle rhythm was established, ordnance loading was handled in the following manner.

Loading three F/A-18s with two live Mk 83s each involved fifteen ordnance personnel. One crew moved bombs to the aircraft while another loaded. The loading crew consisted of ten ordnancemen (Mk 83s are twice as heavy as BDU 45s). In addition, a CAD crew and fuzing crew operated concurrently with the loading (two to three individuals). The fuzing time was highly variable, taking from 2.5 to 4 minutes per aircraft. The time from when weapons left the bomb farm to the completion of the quality assurance checks on three aircraft was twenty-five minutes.

By comparison, [13] reports that an F/A-18 bomb crew with seven to eight people could load an F/A-18 with eight Mk 82s in about sixteen minutes; move to a second aircraft in four minutes; and load the second aircraft in another sixteen minutes. Thus, a typical F/A-18 squadron with two bomb crews could load four F/A-18 aircraft with eight Mk 82s in thirty-six minutes.

On a per-aircraft basis, the load times for the two cases are similar. During the Surge, a fifteen-man ordnance crew could, on average, load an F/A-18 with two Mk 83s in just over eight minutes. In the latter case, fifteen people in two crews could average the loading of an F/A-18 with eight Mk 82s in about nine minutes. Thus, the smaller loadout seems to compensate, in part, for the longer time required to load the heavier weapons.

Ordnance handling not representative of all scenarios

Other scenarios might place operational requirements on the flight deck crews, requirements that could result in increased turnaround times. We list here only a few examples of such potential requirements. Any increase in turnaround time has the potential to decrease the sortie generation of the battle group.

Aircraft gun loading was not performed in the Surge because guns were not required in the JTFEX 97-2 scenario. The time required to load an aircraft gun is typically twenty minutes without problems, and can be as long as forty-five to sixty minutes if rounds jam the loading equipment. Gun loading also consumes manpower, requiring two or three ordnancemen per squadron. Individuals engaged in gun loading would not be available to load aircraft with other weapons.

The expenditure of Mk 82/BDU 45 weapons exceeded the number typically carried in a carrier's magazine [3]. In a real-world scenario, a greater number of Mk 83 and Mk 84 weapons would have been expended in their stead. Because Mk 83 and Mk 84 bombs are more manpower intensive and time consuming to load on aircraft than Mk 82s, having to load more of them may reduce the number of aircraft the flight deck crews could ready in time for launch, which would in turn reduce sortie generation.

If weapons other than Mk 80-series (for example, forward-firing weapons such as Maverick or HARM) had been required, weapons loading would have been more complicated, most likely resulting in increased time and personnel required to turn aircraft around. Similarly, in scenarios requiring employment of a variety of weapons, aircraft ejection racks must be reconfigured frequently, slowing the turnaround process.

HERO conditions on the flight deck can restrict the use of flight deck radio traffic. Under these conditions, all flight operations would take longer, which would reduce the turnaround capacity of the flight deck.

Aircraft turnaround maintenance

Once chocked and chained, aircraft were serviced by a squadron plane captain. Typically, this individual performed a set of such routine tasks as cleaning windscreens and checking fluid levels. Most service tasks can be performed in parallel with weapons loading and fueling. (The exceptions to this are jacking the aircraft to replace tires and replacing nitrogen or oxygen stores). However, we frequently observed ordnance and fueling crews waiting for servicing

functions to be completed before they could begin their turnaround tasks.

F-14s typically took longer to service than F/A-18s. In part this was because the F-14 requires the aircrew's supply of oxygen to be replaced every sortie, while the F/A-18 onboard oxygen-generating system needs no servicing. F-14 canopies also require servicing with nitrogen after one or two sorties.

Aircraft respotting

In general, aircraft could not be serviced, fueled, or armed until they were tied down. For F/A-18s, this typically was not an issue, as they were taxied into a spot usually on the bow upon recovery. F/A-18s were only respotted if the flight deck was planning a three-catapult launch and needed to rearrange the aircraft on the bow cats. Usually, the fight deck crews were able to park aircraft in spots conducive to conducting turnaround functions. But in a few instances, expediency required aircraft to be spotted in less than optimal places.

F-14s, however, were often respotted to their parking spots on the fantail, Elevator Three, or behind the LSO platform. These spots cannot normally be reached during a recovery because taxiing the F-14s fouls the landing area. The aircraft typically were held on the foul line forward of the island until the recovery was complete, then either taxied or towed back. The order in which aircraft were recovered was critical to ease of operating the flight deck. If F-14s recovered too soon, they occupied space forward of the island, congesting flight deck operations. In these cases, the Handler coordinated with the Air Boss to pause the recovery to allow one or two F-14s to move aft.

Employment of deck-edge elevators

Operationally, not all elevators are equal. On USS *Nimitz*, F-14s occupied Hangar Bay Three (the rearmost hangar bay), which is serviced by Elevators Three and Four. Hangar Bays One and Two, which housed F/A-18s, were accessed by Elevators One and Two, respectively. In addition, individual F/A-18 squadrons were assigned areas in the hangar bay, which determined the elevator that transported their aircraft. This assignment of areas consolidated maintenance in the

hangar bay, but it complicated the Handler's job of managing the elevators.

USS *Nimitz*'s use of elevators averaged one run every 1+15, or roughly once per cycle. Roundtrip elevator runs typically took three to five minutes. Most of this time was spent loading and unloading whatever the elevator was moving. Table 15 shows that Elevator Two was by far the most frequently used. There are several advantages to using Elevator Two: it does not affect flight operations as does Elevator Four; it does not always have aircraft parked on it as is frequently the case for Elevator Three; and it does not disturb the flight deck de-arm area as does Elevator One.

Table 15. Deck-edge elevator use

Elevator	Day 1	Day 2	Day 3	Day 4	Total	Percent
One	6	5	6	1	18	23
Two	11	13	10	7	41[a]	52
Three	3	3	2	2	10	13
Four	3	1	2	3	9	12
Total	23	22	20	13	78	100

a. Every run included either ordnance or bomb skids.

Elevators were used for purposes other than transporting aircraft. As discussed earlier, deck-edge elevators were the primary means of moving weapons staged on the hangar deck to the flight deck. Elevators were also used to transport cargo from the C-2, and to move general service equipment (GSE), nitrogen bottles, and other equipment.

Not all aircraft parked on elevators were destined for the hangar bay. "*Free ride*" aircraft were left chained in place, as this was often easier than moving them off the elevator. In fact, elevator runs were made so frequently that "*free ride*" aircraft were quite common.

Fleet experiences suggest that elevator use is generally restricted to times between launches and recoveries, and [13] finds that such restrictions result in reduced sortie generation potential. During the

Nimitz Surge, however, elevator runs were made both during and outside launch and recovery. Access to aircraft in the hangar bay was relatively unimpeded by events on the flight deck. There were five isolated instances in which mission capable F-14s were in the hangar bay and were needed on the flight deck. As a result, sorties were lost. In these five instances, the Handler decided that the actions required to use Elevators Three or Four (used to transport F-14s) would have disrupted flight deck operations and overall sortie generation would have suffered.

Although flight operations did not prohibit elevator usage during Surge, there were many times when an elevator run was delayed. An example of this occurred on the early morning of 24 July when repeated requests for an elevator run were not fulfilled. This resulted in nine aircraft launching without weapons. We observed many reasons for delays in elevator operation:

- USS *Nimitz* was in a turn. To prevent ocean water from washing over a down elevator, elevators cannot be used in a turn. (Turns were observed to take six to eight minutes to complete.)
- USS *Nimitz* was moving too fast. Again, this is to prevent ocean water from washing over a down elevator.
- An aircraft scheduled for an impending launch was parked on the elevator.
- An aircraft on the elevator was not chained down.
- An aircraft on the elevator destined for the hangar bay was configured with ordnance.
- An aircraft on the elevator destined for the hangar bay had JP-8 taken from an Air Force tanker. JP-8 has too low a flash point and aircraft with JP-8 in their fuel tanks must be defueled or fuel stores diluted with JP-5 before entering the hangar bay.
- An aircraft parked on the elevator was turning.
- An aircraft parked on the elevator was nose- or tail-over-deck.
- An aircraft next to the elevator was fouling the elevator's stanchions.

- Using the elevator would foul the landing area (Elevator Four).
- Ordnance remained to be loaded on the elevator.
- The hangar doors were closed. (This occurred late on 23 July into the morning hours on 24 July, simulating defense against inbound cruise missiles.)
- There were not enough aviation boatswain's mates to man the elevator. (This happened during a particularly stressful time on the flight deck and the plane handlers were occupied with more pressing duties.)
- The hangar bay could not take the down traffic (either because it was full or aircraft had to be rearranged).

Some of the reasons cited above were beyond the control of the Handler—carrier turns or closed hangar doors, for example. Others could be avoided with careful planning and management. Being able to avoid some of these situations is a sign not only of finesse, but also of the luxury of prior planning. Despite its best intentions, the flight deck often found itself barely keeping up with the schedule, and finesse was often replaced with "*getting by*."[9] At times like these, elevator runs often had to wait until there was time to accommodate them. We observed only two cases where this had a significant effect on meeting the flight schedule. The first time, on 21 July, an MC aircraft scheduled for Event One was stuck in the hangar bay and the sortie was missed. The second time, the weapons required for the first event on 24 July were not moved to the flight deck in time to be loaded, resulting in nine strike sorties lost.

Foreign object damage walkdowns

Routine foreign object damage (FOD) walkdowns were scheduled every other 1+45 cycle. Combat FOD walkdowns occur when the flight deck is unintentionally littered with debris. Flight operations cease and all available flight deck personnel participate; it is

9. Operators commented that one of the benefits of the 1+15, 1+15, 1+45 cycle template was the periodic 1+45 cycles gave them additional time to catch up.

disruptive to flight operations and the turnaround process. The frequency of combat FOD walkdowns is an indicator of the fatigue of the personnel on the flight deck. Four combat FOD walkdowns occurred on each of the first three days of Surge; on the fourth, the number jumped to seven. Seventeen of the nineteen combat FOD walkdowns occurred at night.

JP-5 consumption

The *Nimitz* flight deck fuel personnel worked two 12-hour shifts during the Surge, with changeovers at 1000 and 2200. There were six fuels teams per shift. Each crew consisted of one supervisor and two fuelers. The supervisor operated the deck-edge controls, while the fuelers hooked the hoses to the aircraft. In this way, one team could fuel two aircraft simultaneously from a single fuel station that had two hoses available.

USS *Nimitz* has fourteen flight deck fueling stations, for a total of twenty-eight hoses. (Most stations were equipped with two hoses, though some had one and some had the capacity to pump with three hoses, if so configured.) There are five fueling stations in the hangar bay, but these were typically used for defueling aircraft.

Table 16 shows the number of hook-ups and the amount of fuel pumped daily (excluding the airwing fly-off sorties' fuel taken after the Surge). These data include fuel passed to helicopters. Average daily consumption was about 388,000 gallons (2,638 klbs); average give was ten thousand pounds per hook-up. There were more hook-ups recorded (1,026) than sorties flown (975). These extra hook-ups could have been for rotary-wing aircraft, aircraft that went down before launch, or for those instances where fueling was interrupted and resumed after a second hook-up.

The median JP-5 gives were 13.0 klb for F-14s, 10.1 klb for F/A-18s, 12.4 klb for EA-6Bs, 7.8 klb for E-2Cs, and 9.1 klb for S-3Bs. The median overall give for all aircraft was 10.1 klbs. Since it takes approximately one minute to pump a thousand pounds of JP-5 [10] and an additional five minutes to hook up and disengage the hoses, F/A-18s

and F-14 were fueled in approximately fifteen and eighteen minutes, respectively.

Table 16. JP-5 daily consumption[a]

Date	Number of hook-ups	JP-5 consumed (klbs)	JP-5 consumed (gallons)	Rate of consumption (gallons/hour)
20 July	141	1,336.2	196,500	16,375
21 July	254	2,562.0	376,765	15,699
22 July	226	2,372.1	348,838	14,535
23 July	267	2,820.4	414,765	17,282
24 July	138	1,462.5	215,074	17,923
Total	1,026	10,553.2	1,551,942	average: 16,166

a. Excludes approximately 43,200 gallons provided for the CVW-9 fly-off.

We did not observe queuing for fueling crews. There appeared to be sufficient hoses and personnel to service all aircraft in all spots. Fueling could be conducted concurrently with most turnaround evolutions, with the exception of aircraft jacking, nitrogen servicing, CAD loading and removal, fuzing of live weapons, and times when the aircraft's electrical systems were activated. Delays in completing turnaround due to fueling were almost exclusively because the fueling crews had to wait for these other functions to be completed before the fueling could start. Occasionally, crews started fueling, but were forced to stop to allow other turnaround tasks (including respotting of the aircraft) to occur. The delay in these situations added an additional five minutes to unhook and hook up the fuel hoses.

Operating from a nuclear-powered carrier[10]

Operating from a nuclear-powered carrier brought advantages that are not resident in current conventionally powered carriers: greater speed, larger aviation fuel capacity, and a larger weapons inventory. USS *Nimitz* and CVW-9 used them all to achieve the high level of

10. We would like to acknowledge the Navigator on board USS *Nimitz* for his contributions to this sub-section.

firepower they generated during the Surge. Successfully maneuvering USS *Nimitz* to accommodate flight deck operations became increasingly challenging during the Surge for several interrelated reasons.

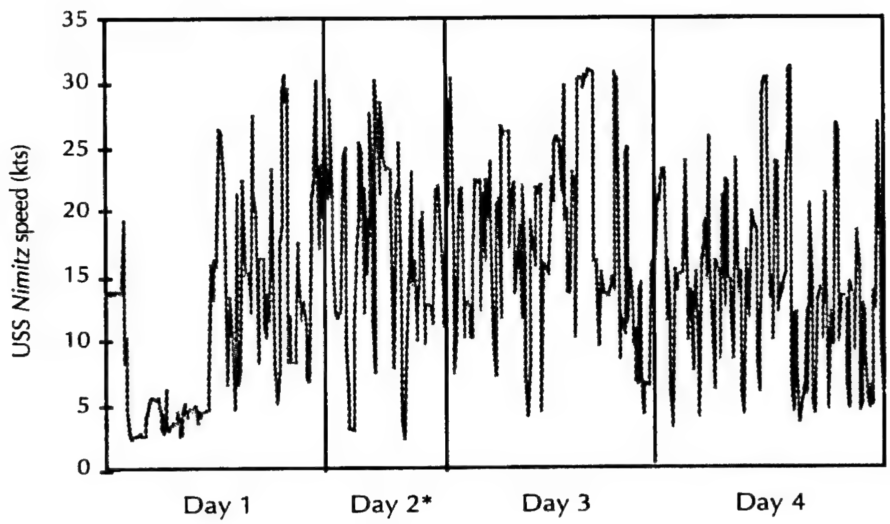
All flight operations are driven by winds. During this scenario, USS *Nimitz* encountered the full range of wind conditions, from light and variable to sustained winds between twenty and twenty-five knots to the standard Southern California northwesterly winds between ten and fifteen knots. Each of these conditions presents challenges for the Officer of the Deck (OOD):

- Light and variable winds generally allow the OOD to choose a heading that best suits the prescribed operating area. The disadvantages to light and variable winds are that a higher ship speed is required to meet aircraft launch and recovery requirements and aircraft are forced to land into axial winds. It is impossible to get winds directly down the angle deck when the ship makes its own wind.
- Higher speed (twenty to twenty-five knots), sustained winds are beneficial because the OOD can use minimal ship speed to achieve aircraft launch and recovery requirements. This allows the ship to almost hover at bare steerageway during flight operations.
- The standard Southern California wind between ten and fifteen knots is often the most challenging, especially in restricted waters. It is not enough wind to allow the ship to hover, but it creates significant axial cross winds along the angle deck.

Figure 22 shows the USS *Nimitz*'s speed over the four-day Surge (GPS data).

USS *Nimitz* was restricted to operating in established carrier operating areas. In general, those operating areas were oriented along a northwestern radial. Prevailing winds were from the west and at times prohibited USS *Nimitz* from maneuvering while conducting flight operations.

Figure 22. USS *Nimitz*'s speed during the four-day Surge



** Data missing for 21 July 1150 - 2330*

Key factors in the ability of the ship to meet the launch and recovery requirements in restricted air and sea space are its maneuverability and its ability to meet an order for increased speed. With four main engines on line, a nuclear-powered aircraft carrier such as USS *Nimitz* can launch aircraft while creating fifteen knots downwind, turn 180 degrees, and bring up a full or flank bell between twenty and twenty-five knots in sufficient time to complete a 1+15 or even a 1+00 cycle. The responsiveness of the main engines is critical because the sequence is demanding: launch the last aircraft in the event, turn 180 degrees, and, by the time the wind over deck is sufficient for recovery, the first aircraft is over the landing threshold. This is all within six to eight minutes.

Although in this scenario the *Nimitz* battle group had attained battlespace dominance before the Surge began, the USS *Nimitz*'s ability to quickly attain high speed greatly eased the defense of the carrier. In other scenarios, this capability might allow a greater proportion of battle group assets to be dedicated to offensive actions than would be prudent with operating from a conventionally powered carrier.

In current nuclear-powered carriers, all fuel tanks can be used to store JP-5. The current conventionally powered aircraft carriers use some of the fuel tanks to store fossil fuel to power their engines. Having a greater capacity of JP-5 on hand increases the time before replenishment of JP-5 is required. Indeed, current conventionally powered carriers would have depleted all their JP-5 stores before the end of the Surge; USS *Kennedy*, for example, would have required JP-5 replenishment on the third day of the Surge.

The weapons inventory of a nuclear-powered carrier is greater than that of current conventionally-powered carriers, carrying one-third more Mk 82 and Mk 84 bombs and one-fourth more cluster munitions [3]. With the nominal weapons inventory for a conventionally powered carrier, the carrier's magazine (without replenishment) would have been almost empty after the four days of the Surge.

Maintenance and supply

How did maintenance and supply affect Surge sortie generation? We found that during the Surge fifty-eight scheduled sorties were missed, forty-nine of which were missed for maintenance or supply reasons. Our analysis focused on maintenance and supply in two major areas: *aviation* systems and *ship* systems. Aviation systems were the root cause of all the missed sorties attributable to maintenance or supply. One F/A-18 squadron accounted for over half of the missed sorties and the F-14 squadron accounted for almost one-quarter of the missed sorties.

We used extensive on-scene data collection and observation to support our analysis. We also relied on the NALCOMIS aviation data to support conclusions about the aviation logistics support provided during the Surge. We supplemented the manually collected data with squadron and aviation materiel maintenance and management (AV3M) data.

We collected the following data during the Surge:

- Mission-capable (MC) rates as observed in Flight Deck Control
- Aircraft materiel readiness reports (AMRRs)
- Daily casualty reports
- Aviation production control reports, including initial stock positions and daily fill rates
- General service equipment (GSE) availability
- Ordnance handling equipment availability
- Preventive maintenance schedules
- Catapult and arresting gear maintenance action forms
- Cat/trap logs.

To assess whether USS *Nimitz* and CVW-9 maintenance and supply operations changed for the Surge, we compared the Surge results to similar data for CVW-9 during the entire month of July and to a Navy-wide peacetime baseline developed by NAVICP. The NAVICP database includes data for all deployed carriers during the period January 1996 through June 1997. We used only data for identical type/model/series aircraft for the baseline comparison. We compared the readiness and cannibalization rates from the Surge to normal levels one would expect in peacetime.

Although readiness rates themselves may help to explain why sorties were missed, they do not necessarily add insight into how policy and execution supported operations. We analyzed other data in order to do this. Specifically, for aviation systems, we looked at both organizational-level (O-level) and intermediate-level (I-level) maintenance performance by examining awaiting parts, awaiting maintenance, and in-work times to determine whether bottlenecks in the maintenance and supply support occurred and, if they did, the extent to which they limited sortie generation.

For critical ship systems,[12] we analyzed how unexpected failures in these systems affected the Surge and postulated the conditions under which these system failures would have had a more dramatic impact. We examined preventive maintenance schedules to understand what effect they had on the Surge, and how these schedules might affect the sustainability of a Surge beyond four days.

Aviation analysis

The top-level measure we used to look at the effects of maintenance and supply on Surge operations was the number of missed sorties. A missed sortie is one that was scheduled but not launched. Note that the sorties that were launched without ordnance are not considered missed, but rather sorties disqualified from strike.

12. Before the Surge began, CNA analysts and the major divisions of USS *Nimitz* identified and agreed upon which ship systems would qualify as critical to supporting the Surge.

Fifty-eight scheduled sorties were missed during the Surge; forty-nine of these—over eighty-four percent—were missed due to maintenance reasons (aircraft NMC at launch). Other reasons sorties were missed were operations (insufficient time to fuel, spot, or load weapons) or personnel (aircraft not manned). The F-14 squadron and one of the F/A-18 squadrons missed most of the sorties. This section explains why the forty-nine sorties were missed.

Readiness rates

Observed MC rates from Flight Deck Control

During the Surge, we manually collected dynamic readiness data they were received by the airwing's maintenance representative in Flight Deck Control (FDC). Specifically, we recorded the times that aircraft were reported either NMC or MC. We recognize that this method of measuring readiness is not without its problems. Changes in individual aircraft readiness status may not always be received in Flight Deck Control on a timely basis. For example, a few times aircraft were indicated as NMC until the moment they launched. Also, we have no way of discerning FMC versus PMC using these data. Nevertheless, the observed rates give an indication of the real-time readiness information available to the Handler as he considers aircraft movement on the flight deck.

Figure 23 shows the observed mission-capable rates for the F-14 and F/A-18 squadrons as measured in Flight Deck Control. As the figure shows, the F-14 squadron and one of the F/A-18 squadrons had persistent readiness problems throughout the Surge. The other two F/A-18 squadrons did not experience protracted readiness problems, and consequently did not miss many sorties due to lack of MC aircraft.

Table 17 lists the observed MC rates by squadron during the Surge. The last column shows the average observed MC rate over the entire Surge; the other columns track average daily readiness as the Surge progressed. The data show that for the F/A-18s and S-3s readiness declined on Day 1, Day 2, and Day 3; on Day 4, readiness started to rebound.

Figure 23. Observed MC rates from Flight Deck Control

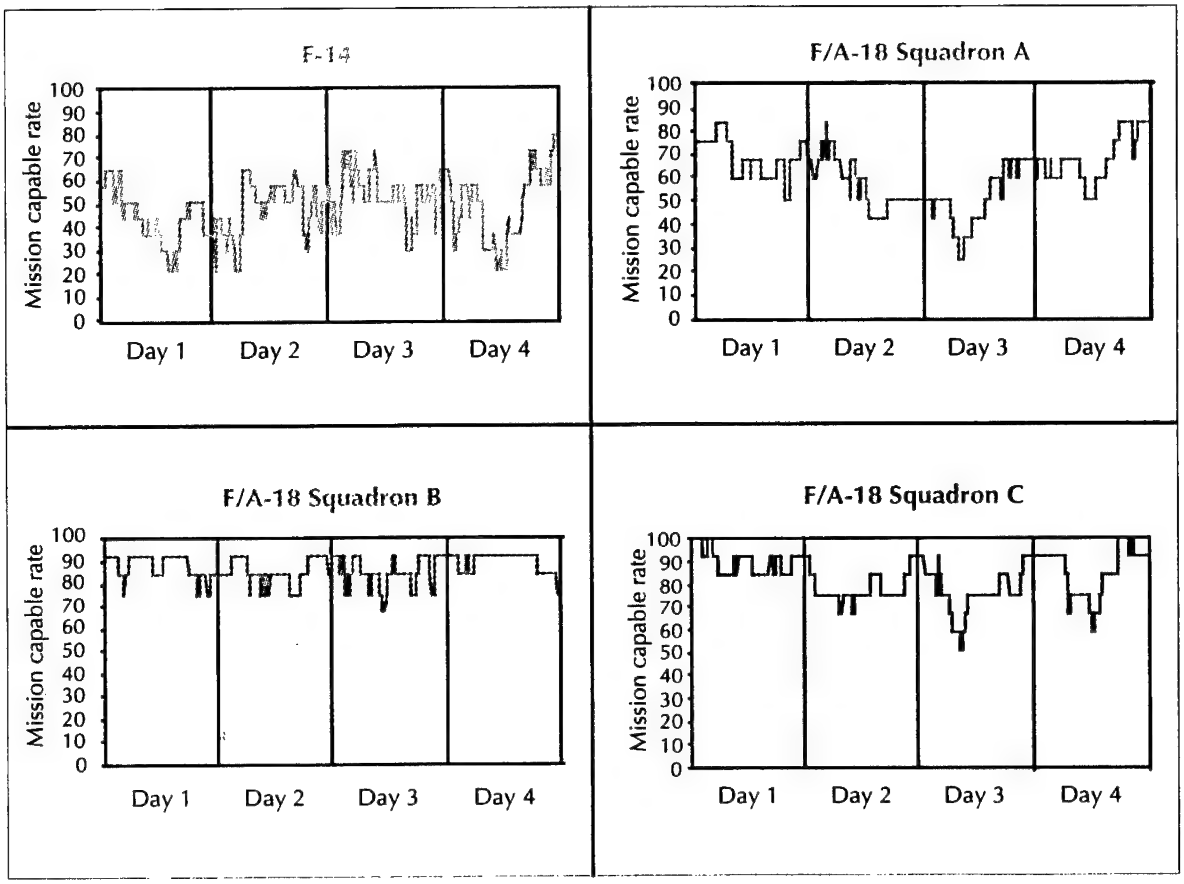


Table 17. 7MC rates observed from Flight Deck Control

Squadron	MC rates at Surge start	Average MC rates (percent)				
		Day 1	Day 2	Day 3	Day 4	Surge
F-14A	64	43	47	53	50	48
F/A-18C						
Squadron A	83	68	56	51	68	61
Squadron B	83	88	85	85	88	86
Squadron C	100	90	78	77	86	83
EA-6B	100	95	92	94	66	86
S-3B	63	84	77	68	73	75
ES-3A	0	44	99	99	66	77
E-2C	100	70	75	79	89	79

AMRR rates

The AMRR is a snapshot in time of the airwing maintenance officer's (CAGMO's) best estimate of aircraft availability two hours in the future. In theory, at the time the snapshot is taken, the results should match the observations from FDC.

We compared the observed MC rates from FDC to the AMRR rates. After accounting for when each AMRR "snapshot" was taken—and using a measurement "window" around this time—we found that except for the F-14 squadron the AMRR predictions were similar to the observed rates. The AMRR for the F-14 squadron reported three more MC F-14 aircraft each day than what was actually observed from FDC. There are several possible explanations for this discrepancy:

- The F-14 squadron may have been overly optimistic about how quickly they would be able to fix NMC aircraft.
- The F-14 squadron may not have been aggressive in reporting changes in aircraft status to Flight Deck Control.
- Reported changes in F-14 status were not noted as expediently in Flight Deck Control.

We consider the latter of these possibilities to be unlikely because we did not find discrepancies for the other aircraft types. After the Surge, the F-14 squadron reported that their reports to FDC of when aircraft became MC may have been time-late.

AV3M readiness rates

The AV3M readiness rates are based on the detailed maintenance action form (MAF) data collected by the AV3M system. Gripes on the MAFs are given equipment operational capability (EOC) codes, which indicate whether the gripe is mission-degrading. Thus, AV3M readiness rates are directly tied to MAF data. The accuracy of these readiness rates is not without problems—delays in or absence of EOC coding can lead to inflated readiness indications.

Unfortunately, the AV3M readiness calculations are complex, and take time and computing power to complete. For this reason, they are not computed real-time and are not of tactical use to the battle group.

After the Surge, we calculated the AV3M readiness rates using the standard Subsystem Capability Impact Reporting (SCIR) formula. Table 18 compares the AV3M rates for each squadron to our observed MC rates and the Navy-wide baseline. Note that the AV3M MC rates were within a few points of the observed data for most of the squadrons. However, the readiness of F/A-18 Squadron A and the F-14 squadron was noticeably lower than the Navy-wide baseline. This indicates that the availability of aircraft for those two squadrons was potentially more of a limiting factor during the Surge than it might normally be.

Table 18. Comparison of MC rates by squadron

	MC rates (percent)			
Squadron	Observed in FDC	AV3M	AMRR	Deployed aircraft 1/96 to 6/97
F-14A	48	55	73	70
F/A-18C (composite)	77	81	84	78
Squadron A	61	77	62	
Squadron B	86	82	79	
Squadron C	83	84	75	
EA-6B	86	95	82	78
S-3B	75	79	80	70
ES-3A	77	56	79	79
E-2C	79	85	94	81

Note that even though F/A-18 Squadron A missed thirty-five sorties, the combined F/A-18 readiness was about normal.

Maintenance ability to meet MAAP demand

One way to assess whether the maintenance of strike/fighter aircraft kept pace with anticipated demand is to measure whether there were sufficient numbers of MC strike/fighters (either on the flight deck or scheduled to recover) to meet the MAAP requirement for two launches in the future. We used this criterion because it closely resembled that used by the *Nimitz* OHO for his reserves of ordnance on the flight deck.

Figure 24 shows the number of MC F/A-18s (on the flight deck or scheduled to recover) in excess of that required to meet the next two launches. You will note periods when the number of F/A-18s was insufficient (the shaded regions in figure 24). These were the periods in which F/A-18 sorties typically were missed. But on average, there were 3.8 F/A-18s in excess of future demand.

Figure 24. F/A-18 airframe capacity to meet future demand

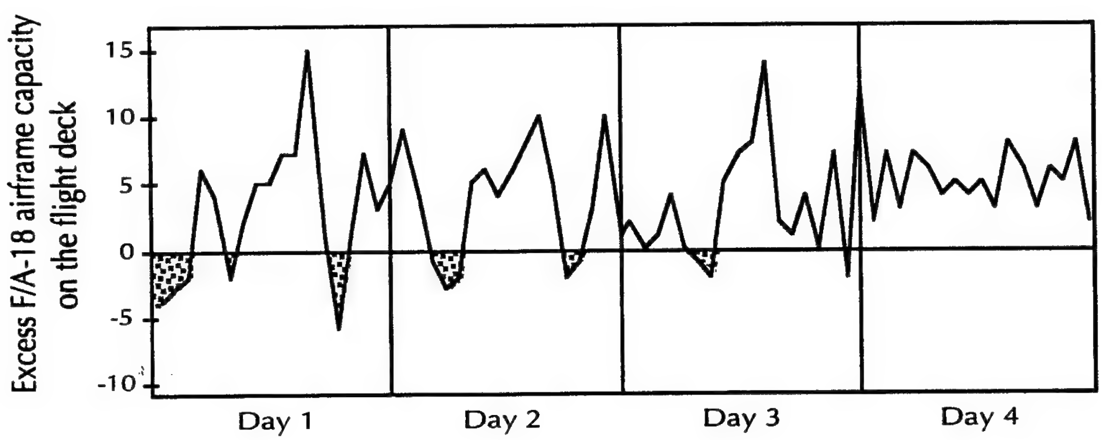
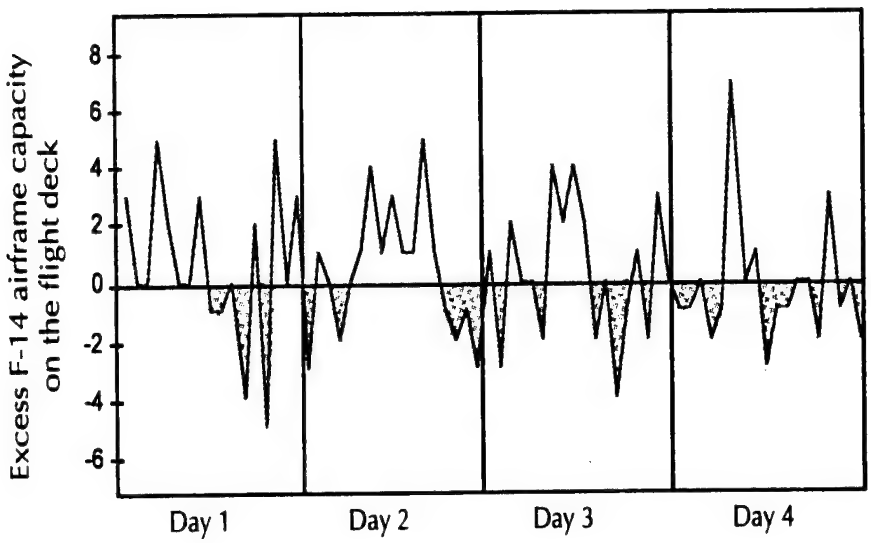


Figure 25 shows a similar plot for the F-14s. You will note many more periods when the number of MC F-14s was insufficient to meet future demand. In fact, on average there was less than 0.3 F-14 in excess of the future demand. This indicates that the MAAP demands on the F-14 squadron were close to the maintenance/supply capacity to sustain operations.

Figure 25. F-14 airframe capacity to meet future demand



Maintenance activity

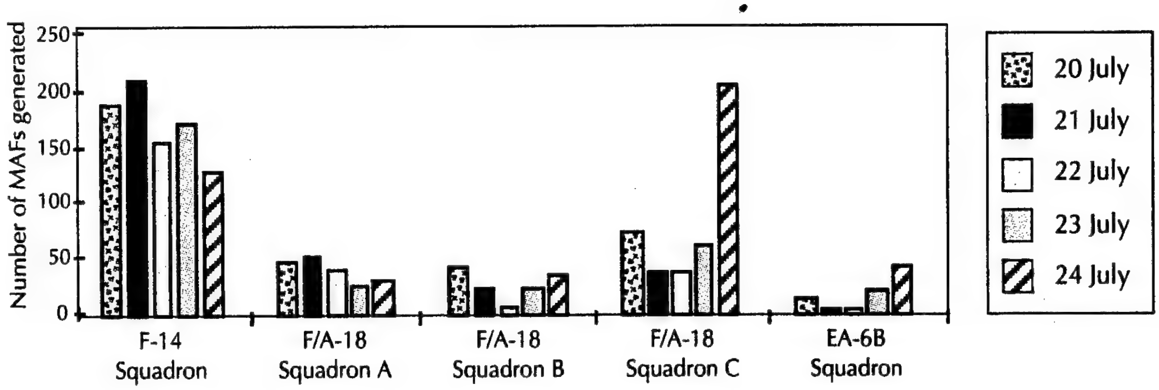
Maintenance action form generation

We tracked the generation of MAFs for the entire month of July. In particular, we tried to determine whether any squadrons delayed generating MAFs until after the Surge ended. We found that generally the squadrons generated few MAFs in the days immediately following the Surge.[13]

Figure 26 shows the number of MAFs generated for each squadron that flew strike sorties during the Surge. The figure shows that only one squadron reported a dramatic increase in MAFs on the last day of the Surge. We suspect that the rise occurred because this squadron submitted MAFs earlier than the other squadrons.

13. Many USS *Nimitz* and CVW-9 personnel took leave after the Surge. We have anecdotal evidence that in the time period just before deployment the number of MAFs generated as a result of the Surge was large.

Figure 26. MAF generation during the Surge



O-Level maintenance

Cannibalization. Squadron maintenance personnel cannibalize weapons replaceable assemblies (WRAs) for both supply and operational reasons: because there are no ready-for-issue (RFI) replacement WRA parts available (lack of parts in supply); or because there is not enough time before that aircraft is to launch for them to get the part from supply and perform the remove-and-replace action (operational). Cannibalizing WRAs at the O-level is one way to maximize squadron readiness rates. By consolidating as many gripes possible into the fewest number of airframes possible, maintenance personnel can keep readiness rates at their maximum. Without doing this, aircraft readiness could be quite low during high-intensity flight operations or when inventories run low.

As a result, cannibalization rates (normally expressed in terms of the number of cannibalization actions per one-hundred flight hours) are a good measure of logistic performance. The records of cannibalization actions, however, are often suspect. The only source for this information is the AV3M system.

As shown in table 19, the AV3M data revealed low cannibalization rates across all squadrons. We can conclude from this that either the squadrons performed few cannibalizations—a reflection of the short logistics chain during the Surge—or they did not record them. However, analysts observed the F/A-18 squadrons cannibalize aircraft for

gear that had inadequate logistic support—for example, the F/A-18 video recorder and the APG-73 radar receiver.[14] The AV3M data suggests that the two squadrons that accounted for the majority of the missed sorties did not aggressively cannibalize during the Surge.

Table 19. Cannibalization rates as reported in AV3M

	Cannibalization rate		
Aircraft type	USS *Nimitz* during Surge	USS *Nimitz* during July 97	Deployed CVs from 1/96 to 6/97
F-14A	0.91	7.56	11.75
F/A-18 C	1.08	3.49	10.35
EA-6B	7.07	10.25	14.55
S-3B	4.06	10.42	22.53
ES-3A	1.85	3.15	3.22
E-2C	0.00	5.12	20.32

NMC rates. We studied the NMC rates for both supply and maintenance:

- NMCS rates represent the percentage of aircraft that are NMC due to waiting for a part from the supply system.
- NMCM rates represent the percentage of time that aircraft are down due to maintenance causes (either currently under maintenance awaiting an aircraft spot, or awaiting maintenance personnel).

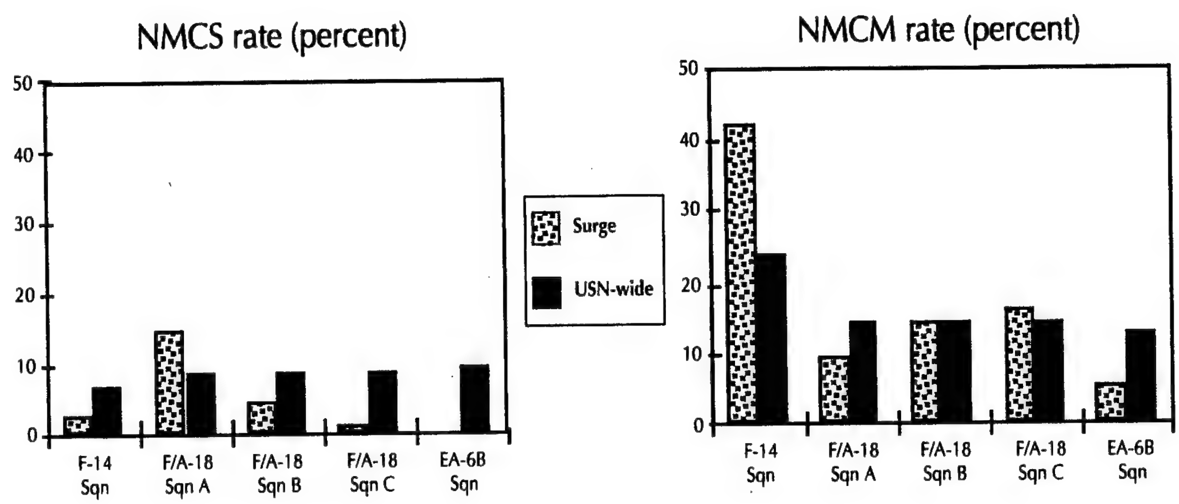
Figure 27 shows the NMCS and NMCM rates for the Surge by squadron. Generally, the NMCS rate was significantly lower during the Surge than the Navy-wide baseline. This finding suggests a high inventory-fill rate during the Surge and an adequate AVCAL to support a four-day Surge operation. USS *Nimitz* AVCAL was at deployment levels with two exceptions. CNAP sent twelve parts anticipating the need for them during the Surge; none of these parts was used.

14. OPNAV N41 confirmed that most deployed F/A-18 squadrons were experiencing similar logistic support problems for these systems and it continues to be a readiness problem.

The F-14 squadron brought a 10,000-pound pack-up kit of spare parts; almost all of these parts were consumed during the Surge. Appendix D (Volume 2) lists the specific parts brought on board by the F-14 squadron.

F/A-18 Squadron A, however, had a higher than anticipated NMCS rate during the Surge. USS *Nimitz*'s AVCAL and on-shore depots did not support this squadron as well as it did the other squadrons. Clearly, an insufficient AVCAL for some critical parts affected their readiness. These parts included such items as the F/A-18 video recorder and APG-73 radar receiver. Appendix D includes a list of the problem parts.

Figure 27. Surge NMCS and NMCM rates



Note also that the F-14 squadron showed a very high NMCM rate. This suggests one or more of the following:

- The number of squadron maintenance personnel to service the aircraft was insufficient.
- Aircraft were not spotted in locations that allowed maintenance actions.

- A substantial number of aircraft were undergoing maintenance during the Surge.

To better understand what was driving NMCM rates, we examined O-level turnaround times and their component measures.

Turnaround times. We compared O-level turnaround times (TATs) recorded during the Surge to those recorded over the entire month of July (including the Surge). These data appear in table 20.

Table 20. Average O-level turnaround times by squadron

	O-level TAT (hours)	
Squadron	Surge	July 97
F-14A	0.83	1.36
F/A-18C		
Squadron A	3.32	2.27
Squadron B	4.42	2.22
Squadron C	1.94	1.79
EA-6B	1.02	1.34
S-3B	4.73	2.86
ES-3A	1.23	1.49
E-2C	0.76	2.05

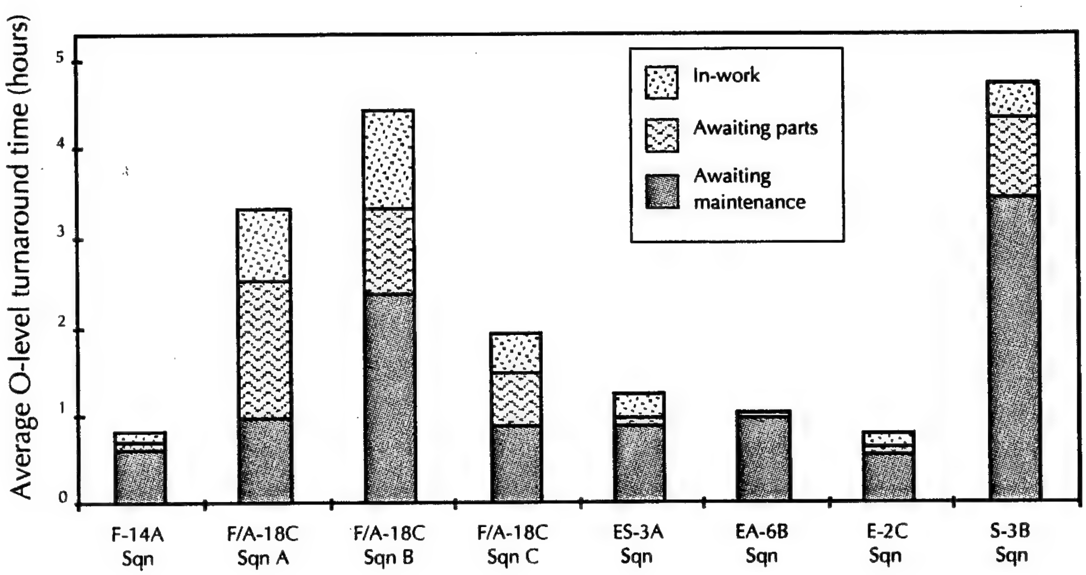
Somewhat surprisingly, the F-14 squadron had a lower average O-level TAT during the Surge than over the entire month of July. We conclude, therefore, that maintenance actions on F-14s were being completed in a timely fashion—but there were so many of these actions to complete that the F-14 NMCM rate rose dramatically. This suggests that more F-14 squadron maintenance personnel were needed to handle the maintenance actions required.[15]

15. The F-14 squadron had left ashore twenty-six of their 266 maintenance personnel. After the Surge, the F-14 maintenance officer estimated the squadron required their full complement of maintenance personnel augmented by an additional thirty-seven individuals.

Interestingly, the squadron with the highest readiness—F/A-18 Squadron B—also had the second highest turnaround time. This finding indicates this squadron had relatively few maintenance actions to perform.

The F/A-18 and S-3 squadrons had O-level TATs greater than their July averages. We decomposed the TAT into its components and found that fifty-eight percent of the TAT was time awaiting maintenance, twenty-four percent was time awaiting parts, and nineteen percent was time in-work. Figure 28 illustrates the components of TAT for each squadron during the Surge.

Figure 28. Components of O-level turnaround times



That the majority of the TAT was spent in the awaiting maintenance (AWM) category tells us two things:

- Enough WRA assets were available during the Surge to perform the remove-and-replace function at O-level maintenance.

- Additional squadron maintenance personnel might have yielded higher readiness rates.

I-level maintenance

Turnaround times. Table 21 compares I-level turnaround times for various aircraft type during the Surge to TATs during July. Note that the I-level TATs were twice as high during the Surge than they were during the month of July.

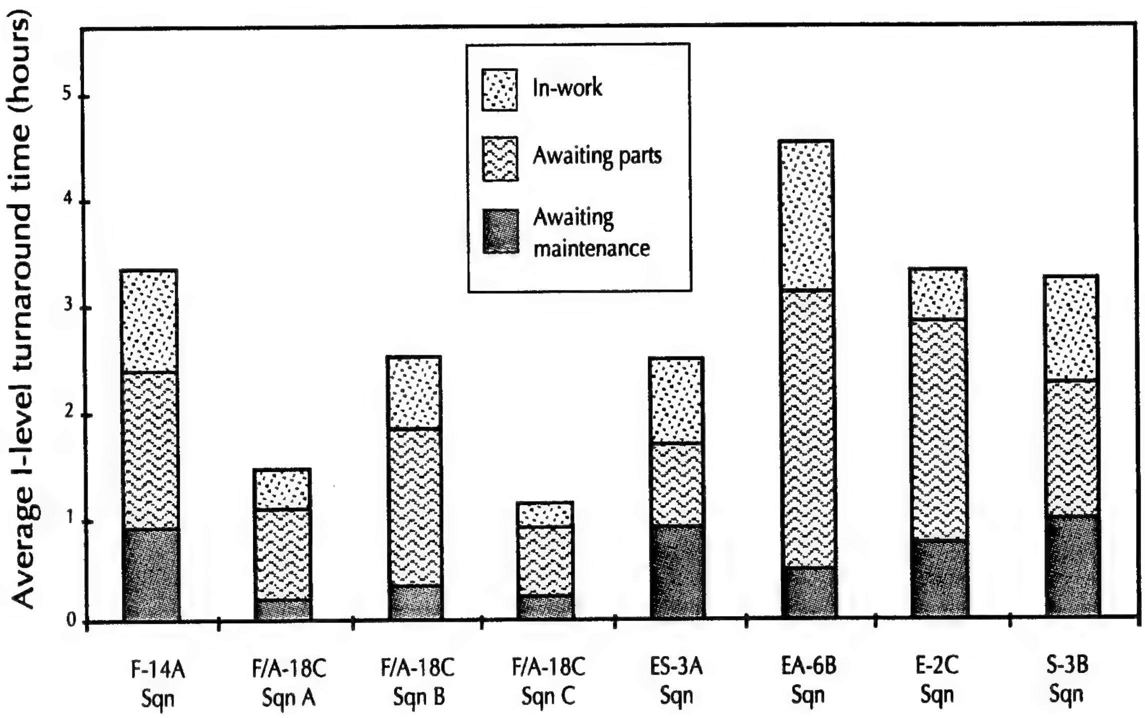
Table 21. Average I-level turnaround times by aircraft type

	I-level TAT (hours)	
Aircraft type	Surge	July 97
F-14A	3.35	1.78
F/A-18C	1.67	1.17
EA-6B	4.44	2.05
S-3B	3.23	1.67
ES-3A	2.50	1.59
E-2C	3.68	2.07

The problem was not insufficient numbers of personnel in AIMD. Instead, we discovered, that the majority of the I-level TAT was spent waiting for supply parts. This indicates that the inventory of repair parts (lower-level indentured parts to the WRAs) was insufficient to keep up with the demand. Therefore, augmentation of repair parts needed to fix WRAs (i.e., SRAs and piece parts) is probably necessary to sustain Surge operations. The components of I-level TAT are illustrated in figure 29.

BCM rate. Another measure of AIMD maintenance capability is the beyond the capability of maintenance (BCM) rate. The BCM rate is the portion of all AIMD inductions that could not be repaired and had to be evacuated to the depot-level of maintenance off USS *Nimitz*. The BCM rate recorded for the Surge was no higher than the Navy-wide baseline rates. We do not currently hold the data on the number of parts that were sent to the CONUS AIMD after the Surge was over.

Figure 29. Components of I-level turnaround times



Wholesale logistic response time

Total wholesale logistic response time (LRT)is a measure of the supply system on board USS *Nimitz* and the logistics system off USS *Nimitz*. It is the total time from when a squadron requests a replacement part to when it is received. The O-level and I-level TATs constitute the on-ship portion of LRT. Wholesale LRT (the time it takes to receive a part from the wholesale system) also has a big impact on aircraft MC rates.

During the Surge, parts in high demand and low availability (such as the F/A-18 video recorder and APG-73 radar) were expedited from shore stations to USS *Nimitz*. These parts arrived by COD within a few hours of request. Our analysis indicates that when response time is decreased to a few days, there is little difficulty supporting a high-intensity operating tempo for an extended period of time.

However, the twelve-hour wholesale LRT experienced during the Surge was an exercise artificiality. For comparison, when carriers deploy to the Persian Gulf, they average a *20-day* wholesale logistic response time for low priority items; for high priority items, five to six days is typical.

GSE availability

We tracked the availability of GSE through regular reports from the IM4 Division and GSE maintenance recorded in the AV3M data. GSE readiness was consistently high during the Surge and had no adverse effects on Surge operations.

However, all Mk 82/83 loading is done manually, without the aid of hoists. Had the weapons configuration included other types of ordnance, the reliability of the hoists—historically low—might have been a factor.

Critical ship systems analysis

Before the Surge, we met with representatives of the *Nimitz* V-2, V-3, V-4, A and E divisions to discuss their concerns about the Surge. The divisions identified the ship systems they thought would be critical to the success of the Surge:

- Catapults
- Arresting gear
- Radars
- Elevators (both weapons and deck-edge)
- Aircraft Electrical Support System (AESS)
- Weapons handling equipment.

Undoubtedly, there are many other systems that might adversely affect flight operations. The above systems, however, were the focus of our study. We sought to understand how they might limit high-intensity flight operations and affect USS *Nimitz*'s and CVW-9's sortie generation potential.

We found that (failures of) these systems had little effect on the ability of the carrier to carry out its planned flight deck operations. Moreover, preventive maintenance was intentionally scheduled to be conducted outside of the Surge period. Many systems' preventive maintenance schedules (PMS) call for work on a weekly basis; hence, this maintenance was either conducted during the sixteen-hour no-fly period immediately before the Surge or scheduled for the post-Surge period.

Some of these critical systems did fail during the Surge and the USS *Nimitz* and CVW-9 team did have to find ways to deal with the failures. The following sections describe these failures, how PMS and some routine maintenance was conducted during the Surge, and the conditions under which these critical ship systems might come to be the limiting factors in future high-intensity flight operations.

Catapults

The maintenance that each of the four catapults requires can be broken down into work done on an annual, semi-annual, quarterly, monthly, weekly, or periodic basis.

All weekly (and longer interval) maintenance was conducted outside the Surge period. The brevity of the four-day Surge permitted this. For example, the weekly R-27 inspections were conducted 17 to 19 July. These inspections included testing the actuate launch valve stroke timers and the capacity selector valve system, and inspecting and lubricating the water brake components. OPNAV 4790/85 suggests that these inspections would require about three man-hours to complete. Thus, if these maintenance actions were required during the Surge, each catapult undergoing R-27 would probably be down for at least two cycles. Surge periods of a week or more would either require some PMS during operations or a waiver of these requirements.

Periodic maintenance is normally dictated by how often the catapults are used; for example, shuttle inspections (R-7 inspections) must be conducted every 400 to 500 shots. Other periodic maintenance varies from every 100 to 200 shots for lubricating retraction engine assemblies and fairlead sheaves (R-16 inspections) to every 10,000 shots for

replacing the steam cutoff switch (R-25 inspections). The most frequent PMS actions—the R-16 lubrications—took as little as fifteen minutes to complete and were conducted between cycles during the Surge. These actions did not affect the sortie schedule.

No-load tests must be conducted on each catapult every twenty-four to forty-eight hours. There was only one case in which these tests had any impact on flight operations. This occurred on 24 July at about 0300 when no-load tests were conducted on Catapult Two. Catapult Three simultaneously went down due to a failure of the jet blast deflector coolant hose. Thus, a few minutes before a launch of eight aircraft and a recovery of thirteen, only Catapult Four was available. (Catapult One was fouled by aircraft on the "one row.") The no-load tests were completed quickly, the eight aircraft launched from Catapults Two and Four, and all thirteen aircraft recovered on time.

Our observations suggest, however, that if Catapult Two had not been readied as quickly, this launch might have had to be reduced in size in order to make the recovery. Larger launches (which were common in the Surge) would have increased the likelihood of this. The bottom line—extended failures of two catapults, in particular when one is at the waist, may preclude operating at high-intensity operating tempos.

Arresting gear

Maintenance of arresting gear is also conducted on an annual, semiannual, quarterly, monthly, weekly, or periodic basis. The most frequent mandatory periodic maintenance is inspection of the clevis sockets and sheave assemblies once every 300 to every 500 traps. These inspections did not affect Surge operations. Other maintenance (such as changing cables) was also performed on the arresting gear without any noticeable effect on flight operations.

Radars

The SPN 46 has two channels for redundancy. Throughout the Surge, one channel (channel B) was down due to a failed power supply. No recoveries appeared adversely affected by this.

The SPN 46 could not be repaired during the Surge for two reasons:

- The required part was not on board (it was a CASREP).
- Even if USS *Nimitz* had the part, flight operations would have had to have been suspended to do calibration pole checks. Repair to the SPN 46 was assessed as not sufficiently critical to warrant halting flight operations.

Deck-edge elevators

In the *Operations during the Surge* section, we discussed the use of the deck-edge elevators. Except for one period before the 0600 launch on 24 July, running elevators was never a problem. All PMS was scheduled around the Surge. Although deck-edge Elevator One was reduced to slow speed (due to a failed high-speed electrical control valve) for about thirty-four hours, this degradation had little, if any, impact on the ability of USS *Nimitz* and CVW-9 to meet the flight schedule. With so many aircraft on the flight deck or airborne, the hangar bays were relatively empty. Even if Elevator One had been completely inoperable, aircraft could have been transported by Elevator Two and moved once in the hangar bay.

The only significant effect the elevators had on flight operations was when Elevator Two could not be used to transport weapons to the flight deck in time to load the weapons on aircraft for the 0600 launch on 24 July. This occurred for many reasons, none of which was attributable to maintenance.

Aircraft electrical support system

The AESS system provides plug-in power to start aircraft in the hangar bay and on the flight deck. At the start of the Surge, twenty-three of twenty-four deck-edge stations on the flight deck were operational. Only one failure occurred during the Surge, when a cable was inadvertently severed. The station could not be fixed while under way because it required a *cherry picker* (crane) to service. Nevertheless, overlap and availability of the other stations was sufficient and flight deck operations were never degraded by AESS availability.

Weapons handling equipment

Availability of the weapons handling equipment was generally quite high, and keeping this equipment operational was never a concern The only piece of gear, however, that was fully issued (i.e., they had none left in supply) was the Aero 12C bomb skid. This gear acts as an adapter to allow multiple 500-pound bombs or a single 1,000-pound bomb to be moved simultaneously (*"like a wheelbarrow"*).

The allocations for these equipment were a concern. Of the twenty-four types of gear we tracked, only about sixty percent had on-hand inventories that met at least ninety percent of the requests.

Personnel issues

Our analysis addressed three fundamental issues:

- Required manning: What number, qualifications, currency, and proficiency of augmentees were needed?
- Integration of augmentees: How well did the augmentees integrate with resident personnel?
- Command fatigue: How do prolonged high-intensity operations affect personnel in command positions?

For our assessment of personnel issues, we grouped USS *Nimitz* and CVW-9 personnel by the job categories given in table 23. We have several findings and recommendations:

- Certainly, the numbers and types of personnel required will vary depending on the operational situation. We provide in table 22 a first cut at required manning levels for operating tempos comparable to the *Nimitz* Surge. We based these recommendations on data we collected during the Surge, much of which were subjective in nature. Work remains to determine the manning requirements in its entirety. We recommend a further time-management study to determine specific composition of augmentation packages tailored to the requirements of the carrier battle group's mission.
- Establishing trust and rapport between resident personnel and augmentees is critical to achieving full utilization of the augmentees. For some billets this is relatively easy; for others more painstaking measures must be taken. We recommend that, where possible, augmentees be proven in their communities and come aboard with all necessary qualifications. Further, we recommend that supervisors be aware of the requirement for augmentees to prove themselves to their co-workers and look for opportunities for them to do so as soon as they are aboard.

- Standardization of procedures eases the entry of the augmentees into the work place. We recommend that, where feasible, the U.S. Navy establish uniform procedures and train individuals to execute these procedures.
- Establishing trust is most critical for individuals in positions of authority and probably the most difficult to achieve. We recommend that, in general, individuals in positions of authority choose a person from the resident staff to whom to delegate their authority. Thus, the delegate can learn the individual in command's approach to problems and rationale behind his decision-making.
- If individuals in command choose delegates from the resident staff, we recommend that augmentation be provided to fill in for the delegate's normal job.
- Communication and cohesion among resident personnel and augmentees, especially for those in positions of authority, is critical. We recommend that operating procedures be explicitly agreed upon by all parties before the first sortie launches. To ease this process, the resident personnel and augmentees should discuss their options for action under a variety of possible real-world situations. We recommend that the U.S. Navy develop a set of hypothetical situations to facilitate such discussions.

Table 22. Recommended manning levels[a]

Job category	Manning level
CVW-9	
Aircrew	Nomogram is shown in figure 36. Command determination of pilot utilization rate is required. Figure 49 in the *Firepower Capacity* section of this report is a nomogram for determining pilot utilization rate based on expected mission planning, flight, and debrief times.
Plane captains	Surge manning adequate.
O-level maintenance	Table 28 provides a planning factor. Estimate of expected flight hours is required. Recommend increasing Surge augmentation by two to four personnel per strike/fighter squadron.
CAG LSOs	Minimum of 9.
Ordnance loading teams	Minimum of 30 (40 for operating tempos higher than in Surge) for each F/A-18 squadron. Minimum of 36 (56 for operating tempos higher than in Surge) for the F-14 squadron. Other squadron manning TBD.
USS *Nimitz*	
Air Department	
V-1 division	Surge manning adequate. Minimum of 212, the wartime (M+1) requirement.
V-2 division	Minimum of 215. This was based on reported sleep of Surge participants. Agrees with wartime (M+1) manning.
V-3 division	With few aircraft in the hangar bays, job not as difficult as during normal operations. No augmentation required.
V-4 division	Surge manning adequate. Some reduction may be possible.
Weapons Department—ordnance assembly teams	Ninety percent of Surge manning sufficient.
AIMD	Table 29 provides a planning factor. Estimate of expected flight hours is required. Surge manning adequate, but short logistics chain made workload of AIMD artificially low.
Operations Department	
OSPC	Include in future high-intensity operations. Man at Surge levels with an additional four dedicated enlisted support and three additional officers.
CVIC	Man to Surge levels with three additional officers and four additional air intelligence specialists.
Strike Operations	Augment with one Assistant Strike Operations Officer and, if carrier is designated as a level-one JFACC, four qualified CTAPS operators. When operations require coordination with ARG/MEU or USAF units (as it did in the Surge), presence of USMC and USAF liaison officers.
Air Control	Augment to Surge levels.
Individuals in command positions	
Air Operations Officer, Air Boss, Mini Boss	Provide augmentees. Ensure operating procedures are agreed upon by all parties.
All others	Delegate chosen from resident staff. Provide augmentation to assist delegate.

a. Because the number of individuals currently on board may differ from carrier to carrier, our recommendations are cast in terms of the total manning required, including resident personnel.

Table 23. Job categories

Job category	Personnel
Aircraft operation	Pilots, RIOs, NFOs
Flight deck and ordnance operations	Fuel and ordnance-loading crews, aircraft directors, plane handlers, chockmen, catapult officers, LSOs, weapons assembly crews
Maintenance	Squadron-level personnel (ATs, ADs, AEs), AIMD personnel
Mission planning	Operational Strike Planning Cell, CV/CVW intelligence specialists, Strike Operations personnel, CTAPS operators, USMC LNO
Air control	ATCs, AICs, tower personnel, Air Operations personnel
Command	Commanding Officer, USS *Nimitz*; Commanding Officer, CVW-9; squadron Commanding Officers; Handler; CAG Maintenance Officer; Air Operations Officer; Ordnance Handling Officer; CAG Gunner; Air Boss; Mini Boss

We based our findings on the data sources listed in table 24. During the Surge, personnel from the *Nimitz* Safety Department randomly surveyed officers and enlisted personnel (the USS *Nimitz* Fatigue Survey). The *Nimitz* Safety Department also employed a fatigue testing device, known as the FIT™ System.[16] The CNA Personnel Survey was distributed immediately following the Surge.

Table 24. Data sources for personnel issues

Data source	Used to assess
CNA Personnel Survey	Fatigue, work routine, ease of integration, delegation of command issues
USS *Nimitz* Fatigue Survey	Fatigue, performance, sleep, eating habits
FIT System tests	Fatigue, presence of intoxicants
Interviews	Work routine, ease of integration, miscellaneous issues
Cat/trap log	Aircrew utilization and turnaround times
LSO log	Boarding rates and wire trapped
Accident and incident log	Injury rates
EDVR report	Enlisted manning (billets authorized and current on board)
OCDR report	Officer manning (billets authorized and current on board)

16. Participation in the FIT test was optional. The FIT System, manufactured by PMI Incorporated in Rockville, Maryland, was not used to determine fitness for duty.

The following subsections contain a synopsis of the data we collected, followed by a supporting discussion of our the findings.

Survey results

CNA Personnel Survey

The CNA Personnel Survey was tailored to four personnel categories—individuals in command positions, supervisors, resident personnel, and augmentees. The objectives for the survey varied by personnel group:

- Command surveys were designed to assess how frequently and to whom individuals in command positions transferred authority.
- Supervisor surveys collected data on supervisors' perceptions of their workers' performance and how well the augmentees assigned to them were integrated into their unit.
- Resident surveys were used to assess the fatigue of USS *Nimitz* and CVW-9 personnel, their work routines, and their perception of how well the augmentees integrated into existing procedures.
- Augmentee surveys were used to evaluate the fatigue of the augmentees, their work routines, and how well they felt they integrated into USS *Nimitz* and CVW-9 work routines.

We summarize the major findings into four topics: manning levels, fatigue of Surge participants, integration of augmentees, and delegation of command. Because some individuals did not respond to the survey, our findings may not reflect the experiences of all individuals.

Question 1 dealt with manning levels

Most respondents—both augmentees and resident personnel—felt the staffing for their job was adequate, with the exception of the maintenance troubleshooters. Nearly half of the troubleshooters surveyed felt they were undermanned—these personnel averaged fourteen-hour work days.

The troubleshooters are responsible for providing quick-fixes and professional guidance when maintenance gripes are first reported; they must be able to diagnose problems quickly and accurately. Selected from squadron maintenance, the troubleshooters are experienced, capable, trustworthy personnel, probably at least second class petty officers. The squadrons could have increased the number of troubleshooters at the cost of the regular maintenance teams' manning levels. The squadrons chose not to do so. They felt that given their overall manpower, the Surge allocation was best for achieving squadron readiness. These actions argue for increasing the augmentation to squadron maintenance.

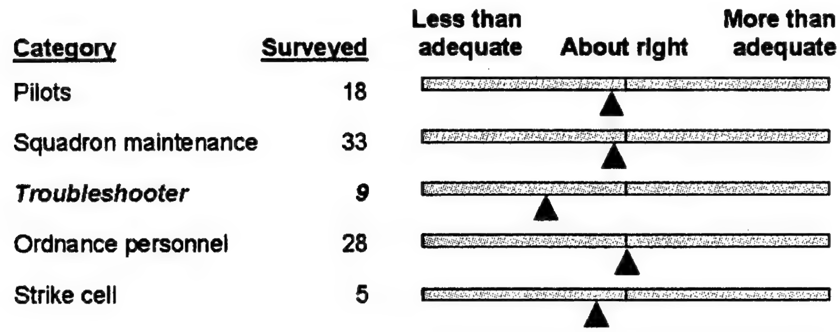
In parallel with this finding, in the *Maintenance and Supply* section of this report, which reported the squadrons' NMCM rates, we found that with additional F-14 squadron maintenance personnel, the F-14 sortie generation might have been greater.

Although the S-3s showed high MC rates during the Surge, the Commanding Officer of the S-3 squadron attributed this in part to good fortune and suggested that the addition of a few more maintenance personnel would have been prudent. Specifically, he recommended increasing the manning by two aviation machinists (AD2) and three aviation electricians (AE2). He felt the additional personnel would be critical were the S-3 squadron tasked with conducting surface warfare or undersea warfare. In addition, he recommended the augmentation include six additional plane captains for the S-3 squadron.

Although AIMD was augmented with ten aviation support technicians to bring them up to their billets authorized (forty individuals), the AIMD floor supervisor felt that three additional workers (AS2/AS3) could have been used.

The EA-6B squadron's Operations Officer felt an additional scheduling officer was needed to relieve the aircrews of all administrative duties and allow them to devote their work-day to mission execution.

Question 1. Do you feel the staffing for your job was:

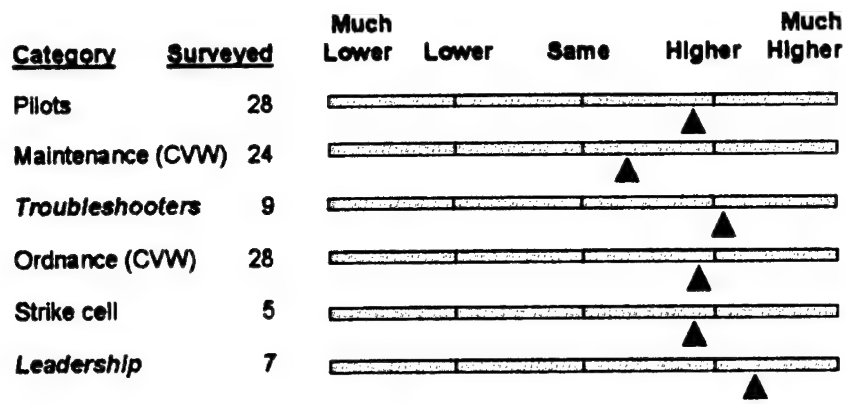


Questions 2 and 3 dealt with fatigue

We asked individuals to assess their fatigue or, in the case of the supervisors, their workers' fatigue. When asked to compare their fatigue level during the Surge to normal operations, most personnel groups felt their level of fatigue was *higher*, but not *much higher*. Individuals in command positions and maintenance troubleshooters reported the highest fatigue. The Surge appears to have had the greatest impact on the commanding officers of USS *Nimitz* and the S-3 squadron. The Commanding Officer of USS *Nimitz* averaged the least amount of sleep and assessed his level of fatigue as being *much higher* than in normal operations. The Commanding Officer of the S-3 squadron also reported having had little sleep. (He also attempted to participate in the FIT fatigue tests, but was labeled *untestable* by the device, perhaps because he was fatigued before the Surge started.)

When asked whether fatigue had a significant impact on their performance, however, the majority felt that it had not. The exceptions to this were individuals in command positions, the troubleshooters, and the Operational Strike Planning Cell (OSPC). About half individuals in command positions and the troubleshooters and nearly two-thirds of the OSPC felt their performance was adversely affected by fatigue.

Question 2: Compared to normal operations how would you assess your fatigue during the Surge?



Question 3: Did fatigue significantly affect your performance?

Personnel category	Resident personnel Surveyed	Yes	No	Augmentees Surveyed	Yes	No
Pilots	19	23%	77%	9	11%	89%
Maintenance (CVW)	22	14%	86%		N/A	
Troubleshooters	*9*	*56%*	*44%*		N/A	
Ordnance (CVW)	9	22%	78%	19	20%	80%
Plane captain	6	0%	100%	3	66%	33%
Strike cell		N/A		*5 of 10*	*60%*	*40%*
Leadership	*7 CO's*	*43%*	*57%*		N/A	

If fatigue did affect their performance, we asked the respondents to rank all the factors that contributed to their fatigue. In table 25, we summarize the rankings for only the individuals in command positions, troubleshooters, and the OSPC because these three groups reported the greatest fatigue. All three groups agreed on the top three factors. The troubleshooters placed more weight on physical exertion as a secondary factor, whereas the individuals in command and the OSPC gave more weight to mental exertion.

Table 25. Factors contributing to fatigue

Factor	Rankings[a] Command positions	Troubleshooters	OSPC
Long work hours	2	1	1 (tie)
Little sleep	1	2	1 (tie)
Few opportunities for rest	3	3	3
Physical exertion	6	4	5
Inadequate accommodations	5	5	6
Mental exertion	4	6	4
Other		Availability of food	

a. A ranking of 1 indicates the most significant.

Table 26 shows the average amount of sleep for these three personnel groups. Although the troubleshooters received the most sleep, their jobs were the most physically demanding.

Table 26. Average sleep for most fatigued personnel

Personnel group	Average sleep (hours) Day 1	Day 2	Day 3	Day 4	Surge
Command	5.3	5.9	5.6	5.6	5.6
Troubleshooters	6.8	7.4	7.3	7.1	7.1
OSPC	5.8	5.6	5.2	5.2	5.4

Although aircrews generally reported that they had sufficient time for crew rest, several pilots commented that abruptly shifting to a night flight schedule at the beginning of the Surge was the greatest factor contributing to their fatigue.

Question 4 dealt with integration of augmentees

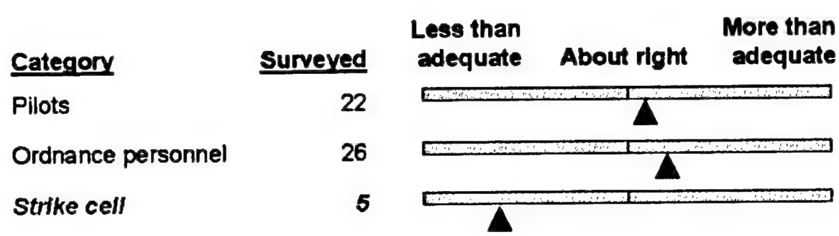
We received surveys back from the OSPC, the aircrew augmentees, and the augmentees assigned to the CVW-9 ordnance department. Only the OSPC felt that they needed more time before the Surge to integrate with the airwing (they flew on board two to three days before the Surge). More important than additional time, however,

they felt that established procedures were needed to more clearly define their duties and responsibilities.

The aircrews felt that arriving on board a couple of days before the Surge was sufficient, as long as they had the opportunity to get at least one carrier launch and recovery before the Surge. Note, however, that all the augmentee aircrew were carrier-qualified before coming on board USS *Nimitz*. Had their currency lapsed, their entry into the strike arena could have been delayed.

The CAG Gunner commented that he was assigned four augmentees with an AO rate, but they had no flight deck experience. Since the augmentees arrived on board about a week before the Surge, there was sufficient time to get them qualified, but "that process took valuable time away from other tasks." The CAG Gunner also felt that no more than one to two days would be required to integrate experienced personnel into the ordnance team.

Question 4. Do you feel the time allowed before the Surge to integrate with resident personnel was:



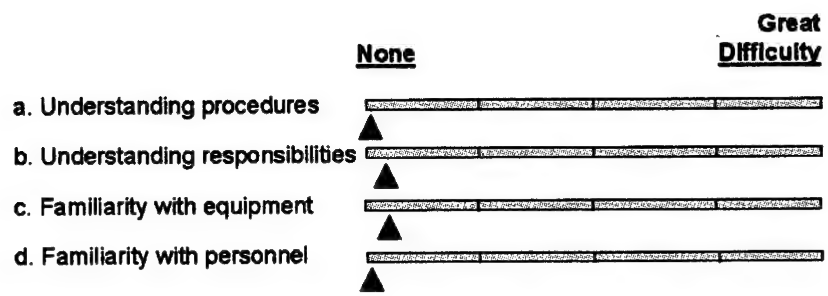
Question 5 dealt with delegation of command

Not all individuals in command positions responded to the survey. However, for those that did, each delegated authority to an individual resident on board USS *Nimitz*, with the exception of the Commanding Officer of the S-3 squadron. (The S-3 squadron Executive Officer was not on board during the Surge.) All commanding officers expressed great confidence in their delegates and indicated that their delegate experienced little or no difficulty in understanding

procedures and responsibilities. Nonetheless, most commanding officers received very little rest or sleep, and, as we noted earlier, half indicated that fatigue affected their performance.

When asked what level of experience their delegate should have, few indicated that it was necessary for him to have held their position in past. Specific qualifications for each position, as cited by survey respondents, are listed in table 27.

Question 5: Indicate how much difficulty your delegate experienced in each of the following areas:



USS *Nimitz* Fatigue Survey

The USS *Nimitz* Fatigue Survey collected data on hours of sleep and individuals' perceptions of how well they were performing their jobs. Figure 30 displays the data they collected. Superimposed on the data is a third-order polynomial curve. This curve illustrates the correlation between the amount of sleep and individuals' assessment of their performance. As expected, there is a highly significant positive correlation[17] between the two variables; that is, the more sleep, the higher an individual's rating of his performance. There appears to be a critical amount of sleep (about three hours) needed for an individual to perceive he is performing at a satisfactory level. The number of hours

17. The correlation coefficient is 0.324 and the significance level is less than 0.0001.

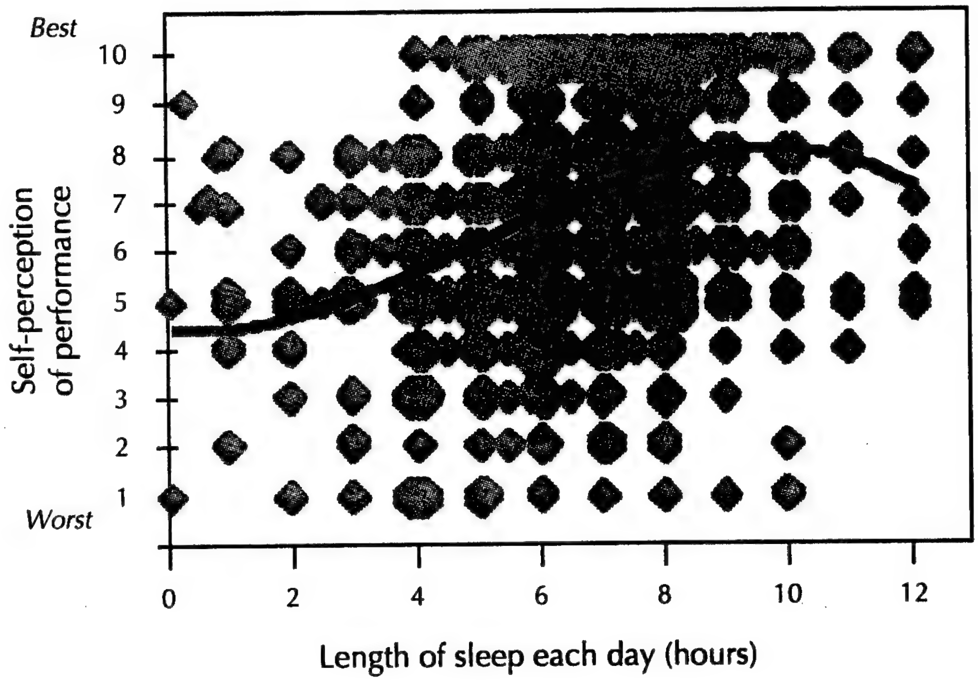
spent sleeping and perceived performance increase fairly linearly until an individual has nine hours of sleep. Sleeping for more than nine hours does little to improve perceived performance.

Table 27. Individuals to whom command was delegated

Position	Delegate	General qualifications
Commanding Officer, USS *Nimitz*	Executive Officer / Navigator	Command qualified. Familiar with carrier operations. Qualified command duty officer under way. On the job training for six months.
Commanding Officer, CVW-9	DCAG	DCAG fully qualified to relieve CAG.
CAGMO	Maintenance Master Chief	
Handler	Flight Deck Officer	LDO with extensive flight deck experience.
Commanding Officer, S-3 squadron	No one	
Commanding Officers, other squadrons	Executive Officer / Operations Officer	Superb aviation skills. Sound judgment. Ability to motivate people. General awareness of carrier flight operations and squadron maintenance procedures. Executive Officers have screened for command and have necessary experience.
Air Boss	Augmentee	Deployed tour as Air Boss within past twelve months.
Mini Boss	Augmentee	Deployed tour as Mini Boss within past twelve months.
Air Operations Officer	Assistant Air Operations Officer/Augmentee	
OHO	G-3 Division officer	
CAG Gunner	E-8 Chief	

We asked ourselves whether various groups of personnel fared differently in terms of the number of hours spent sleeping and their self-perception of performance. First we extracted from the data all responses from enlisted personnel and sorted that data by job category. Figure 31 displays the results for this cut at the data. Within the enlisted personnel, there was little difference among the different worker types with one dramatic exception: the catapult and arresting gear personnel reported significantly fewer hours of sleep and held a lower perception of their job performance than the other enlisted personnel. This finding confirms anecdotal evidence that these workers were stressed more than any other personnel group and would have benefited from augmentation.

Figure 30. Sleep and perceived performance (all personnel)



We also wanted to determine whether there was a significant difference between aircrew and other officers, between officers and enlisted, and between older and younger personnel. Figure 32 displays the results. When compared to the other officers surveyed, aircrews tended to report slightly more hours of sleep and higher estimates of their job performance.[18] There was little difference between the officer and enlisted ranks. Older personnel (more than thirty-five years old) actually reported to have had less sleep than younger personnel. This may be a reflection that older personnel tend to hold more senior positions of authority and responsibility, and they generally "came early and stayed late" to build their own situational awareness and pass on critical information to the next shift.

18. Carrier Airwing Nine squadrons scheduled flights so as to consolidate a pilot's missions into as small a period of time as possible. This maximized the time available for uninterrupted crew rest. Aircrews expressed preference for this scheduling scheme.

Figure 31. Sleep and perceived performance (by billet)

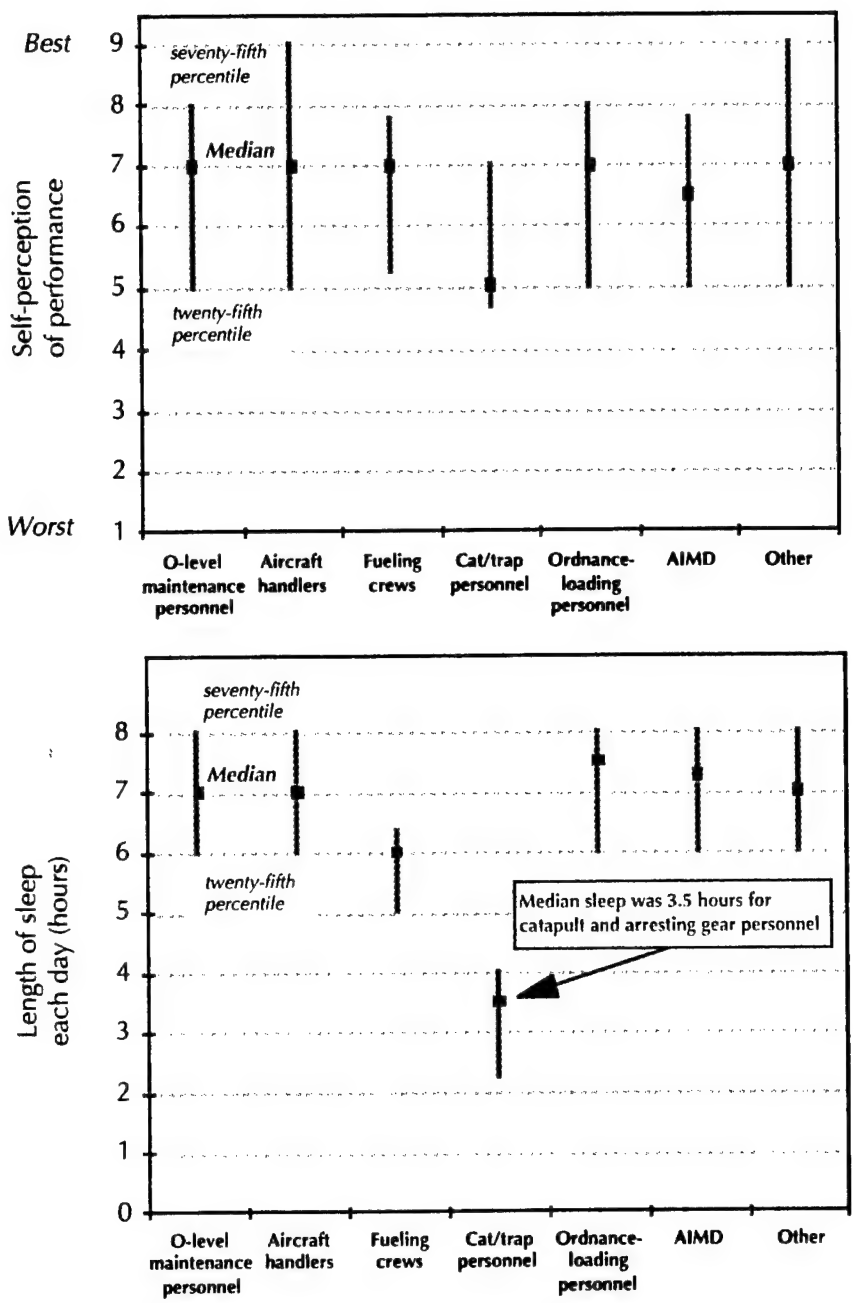
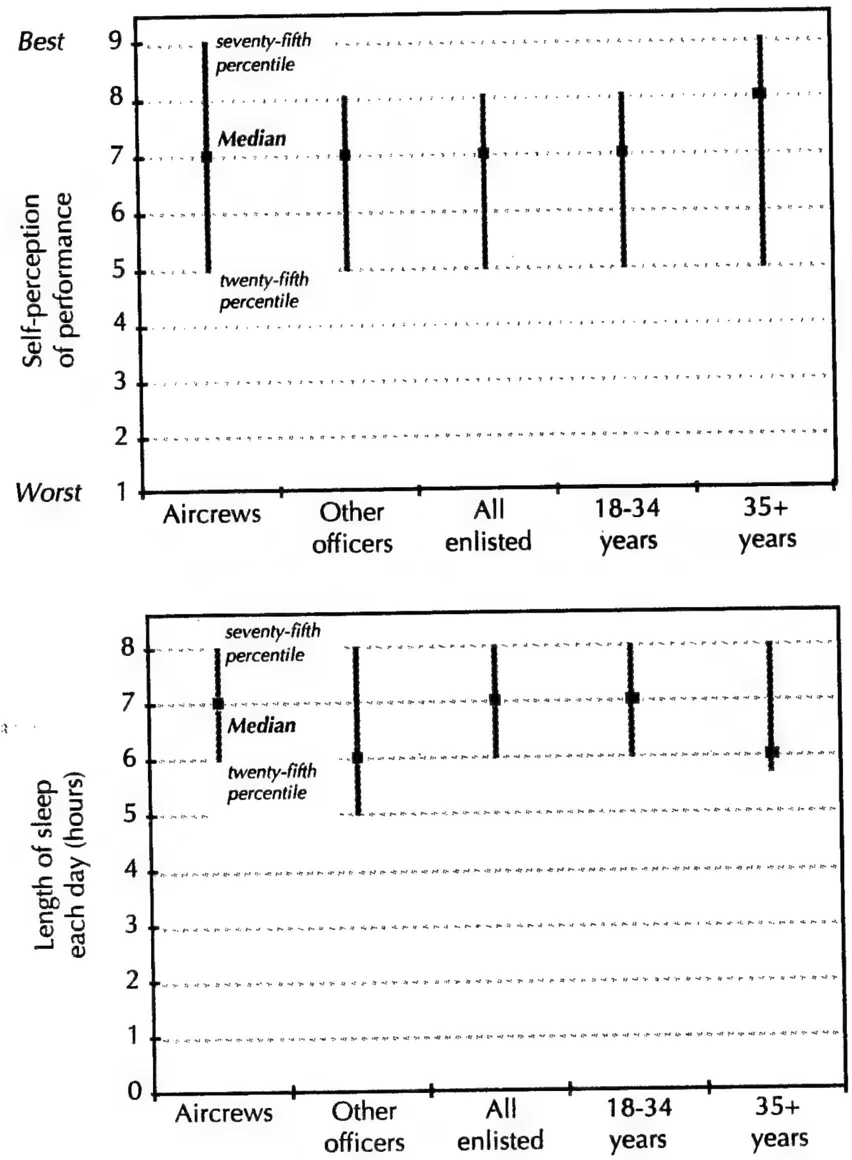


Figure 32. Sleep and perceived performance data (aircrews, officers, enlisted, and age)



Finally, we found that the hours of sleep and self-perception of performance did not change over time.

FIT System test results

The FIT System stimulates the eye with pulses of light and measures both the amplitude and response time of the involuntary eye reflexes. These measurements are compared to the subject's personal baseline to compute the FIT index. This value indicates the likelihood of fatigue; the higher the FIT index, the more likely the subject is fatigued. Most of our analyses are based on the FIT index instead of the FIT test data. We conducted a variety of statistical tests to determine trends inherent in these data. Specifically, we derived the following conclusions:

- There were no significant differences among job categories; however, not all job categories were represented in the data. Specifically, individuals from the crews working on the flight deck and V-2 division did not participate in the test.
- The FIT indices did not vary significantly with time.
- Personnel judged as high risk by the FIT System generally were older and had fewer hours of sleep, yet they did not usually report any serious degradation in their job performance or mental state.
- The number of hours of sleep correlated to the FIT indices if we consider only tests with response times slower than the individuals' baselines. Because the response times are believed to be the best indicators of fatigue in an intoxicant-free environment (when fatigue results primarily from physical strain or lack of sleep), this finding suggests that those measurements responsible for the detection of intoxicants should be suppressed or de-emphasized in the calculation of the FIT index for U.S. Navy applications of the FIT System.
- The amount of sleep appears to be a better indicator of fatigue than the subjective self-assessment of one's physical and mental states.
- The FIT test results did not reflect a circadian rhythm. However, most individuals participating in the test did not have

exposure to sunlight, a factor that may have influenced this finding.

The details of how we arrived at these findings, along with a description of the FIT System and our criteria for establishing baselines, is provided in appendix B (Volume 2).

Other indicators of fatigue

Boarding rates and wire trapped

Results from the CNA Personnel Survey, the USS *Nimitz* Fatigue Survey, and the FIT System all suggest that fatigue did not impair aircrew performance during the Surge. Here, we consider two indirect, but more objective measures of fatigue: boarding rates and the wire trapped on recovery.

Figure 33 displays the day and night boarding rates over the four-day Surge. Overall, there is an improvement in boarding rates from Day 1 to Day 4. In fact, during the final day, which was the heaviest flying day, there were no bolters during the day and only two bolters at night.[19] There is a marked drop in the boarding rates on Day 3; however, the Number Four wire was removed that afternoon and a single pilot accounted for five of the eleven bolters during the day. That night, the Number Three wire was removed for two recoveries.

In figures 34 and 35, we display the distributions of the arresting wire trapped during the day and the night, respectively, for the four days of the Surge. Both the boarding rates and the arresting wire trapped data suggest an *improvement* in pilot performance during the Surge and corroborate the findings from the surveys and FIT test data that the aircrews did not suffer from general fatigue.

19. Bolter rates are discussed further in the *Operations during the Surge* section of this report.

Figure 33. Day and night boarding rates

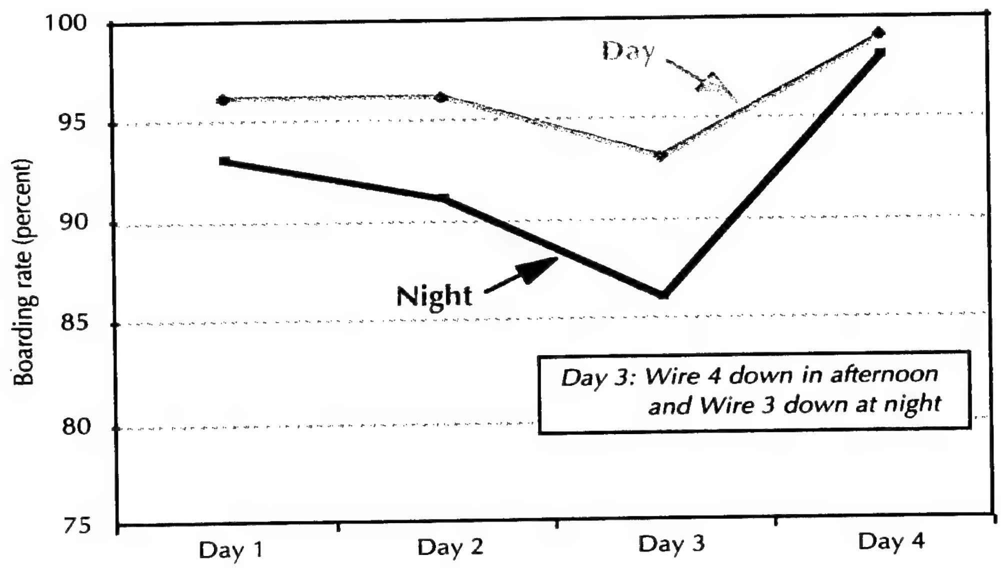


Figure 34. Distribution of the arresting wire trapped, daylight operations

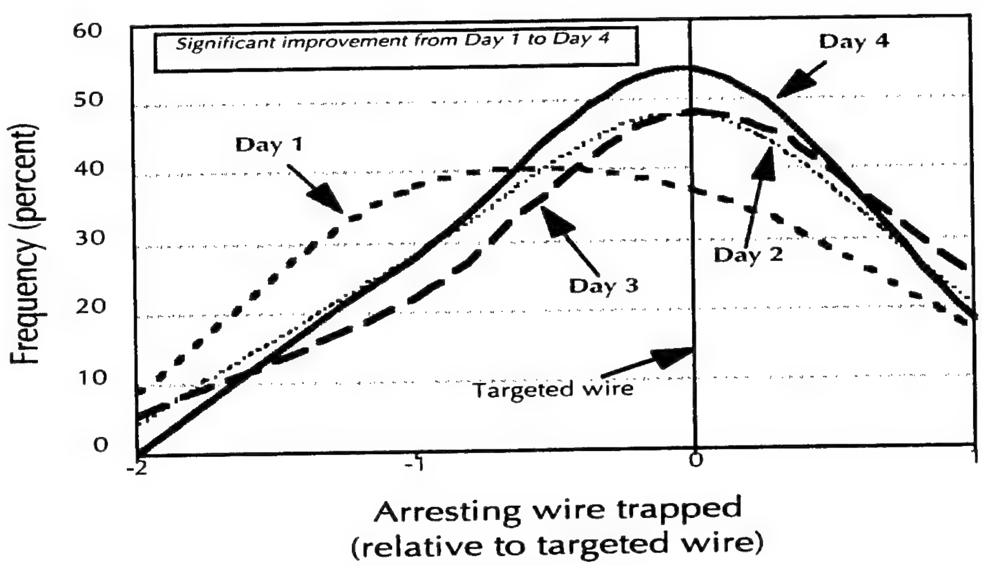
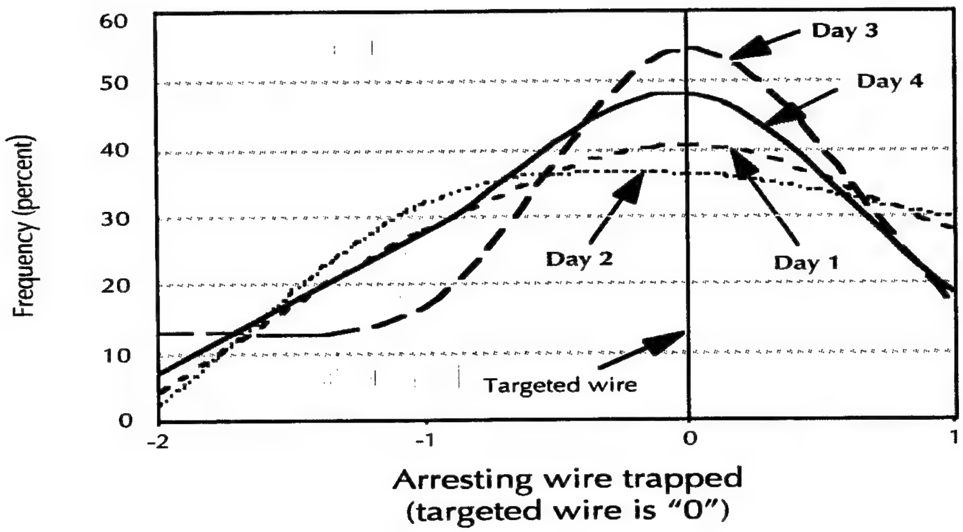


Figure 35. Distribution of the arresting wire trapped, night operations



Injury rate

Over the four days of Surge, thirty injuries were reported on board USS *Nimitz*, for an average of 7.5 per day—a significant increase when compared to the average of 3.3 per day for the six days before the Surge.[20] The daily sortie count, however, more than doubled during the Surge, while the number of night sorties nearly tripled. Thus, the increase in injuries appears commensurate with the increase in operating tempo.

Required manning levels

We turn now to a discussion of the answer to the first question we posed at the beginning of this section. We emphasize again that our results are tentative and further study is needed to refine our estimates. Many factors come into play in determining the workload required of individuals in various jobs. However, the workloads for some jobs depend more heavily on the operating tempo than other

20. Detailed data can be found in appendix B (Volume 2).

factors. Examples of these types of jobs are piloting aircraft and maintenance. In contrast, the tasking for other jobs depends more on the number of hours per day that high-intensity operations are conducted. Examples of these jobs are those of the V-2 division and individuals in command. For jobs falling into the first category, we provide nomograms to estimate the number of individuals required based on the expected operating tempo. For jobs falling into the second category we provide rough estimates of the numbers needed for twenty-four hour operations. Our recommendations are summarized in table 23.

Aircrew

The 2.1 pilot utilization rate was well within the grasp of CVW-9 pilots. We emphasize, however, that the Surge was not combat and pilots were not placed under wartime stress. The operational commander will decide the appropriate utilization rate given the operational situation. As a planning aid, figure 36 shows, at the Surge level of firepower, the tradeoff between the number of strike/fighter pilots available and the pilot utilization rate. We also show in this figure the requirement to sustain operating tempos of ten percent higher and ten percent lower than that of the Surge. For example, at deployment levels of manning, for CVW-9 F/A-18 pilots to achieve the sortie generation of the Surge, each F/A-18 pilot would have to average 2.8 sorties per day.

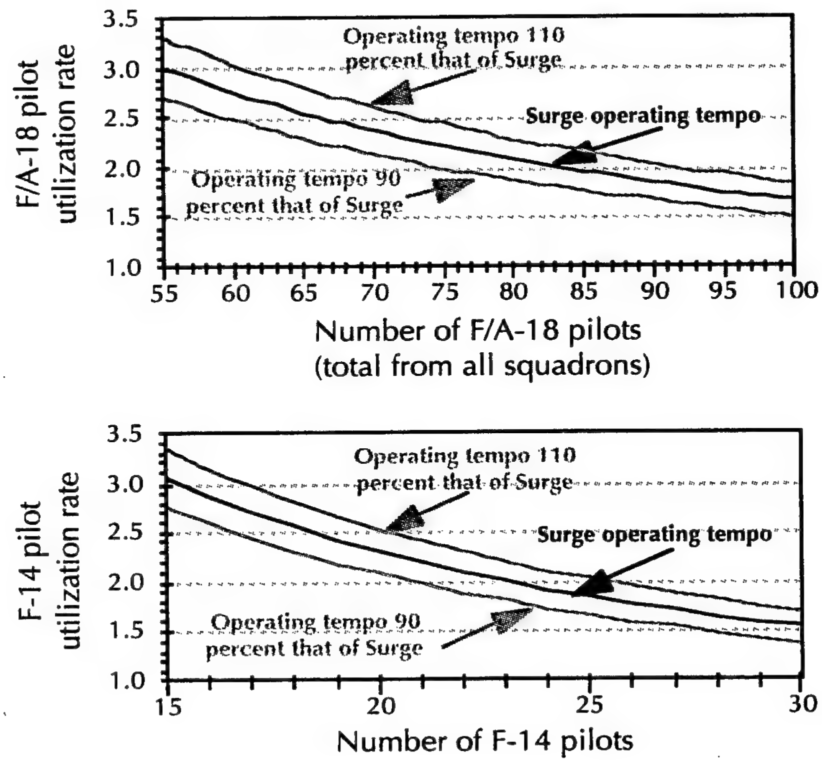
Flight deck and ordnance personnel

V-2 Division

Our data indicate the V-2 division was undermanned during the Surge. But these individuals accomplished their tasks with no serious injuries to personnel or equipment. To enable the personnel in the V-2 division to increase their rest to adequate levels, we recommend increasing their manning to at least two-hundred fifteen personnel.

A USS *Nimitz* chief petty officer suggested manning the V-2 Division to 230 personnel to support continuous operations, with the additional personnel concentrated in the E-4 (i.e., third-class petty officer) and below ranks.

Figure 36. Pilot manning and utilization rate



Ordnance handling

Most respondents to the CNA Personnel Survey felt that the ordnance manning with the augmentees was "about right," with no impact on fatigue.

The weapons-assembly crews reported having more than enough people to accomplish their tasking. Based on their reports of typical length of their work-day, we find they could have been staffed at ninety percent of Surge levels and still met their objectives.

Each F/A-18 squadron divided its ordnance-loading personnel into two fifteen-man crews; each crew worked a 12-on/12-off schedule. This arrangement appeared by-in-large sufficient to keep pace with the ordnance expenditure. On ten occasions, however, ordnance

personnel were unable to arm strike/fighters with ordnance in time to make the scheduled launch.[21] Nine of the ten occurrences were from the same F/A-18 squadron, which may indicate that this squadron was undermanned.

Neither the EA-6B nor the S-3B squadron received additional ordnance personnel. The Commanding Officer of the S-3 squadron estimated that, if S-3B aircraft were flying continuous ASUW missions and delivering ordnance, their ordnance shop would have required an additional four to six personnel to assist in preparing aircraft, testing armament systems, and loading ordnance. Similarly, the CAG gunner estimated that the EA-6B squadron would have needed two to three additional personnel if they had been delivering HARM missiles.

In the next section, we address the limits to sortie generation had the *Nimitz* MAAP called for a higher operating tempo. We find that to significantly increase the sortie generation of USS *Nimitz* and CVW-9, the number of airwing ordnance teams would have to be increased.

For these reasons, we recommend that in future high-intensity operations the airwing's ordnance crews be augmented to at least Surge levels, and strongly suggest increasing the ordnance crews to allow creation of another loading team.

Landing Signals Officers

The two CVW-9 Landing Signals Officers (LSOs) were augmented with five CAG LSOs for the Surge. This freed the squadrons from providing LSOs, thereby reducing the pilots' workloads. A three-man team was fielded continuously throughout the Surge, which presented a significant workload to these LSOs. We recommend that in future Surge operations the airwing be augmented to a manning of nine airwing LSOs.

21. Nine other strike/fighters launched without weapons due to insufficient ordnance on the flight deck (not a lack of time to load the aircraft).

Maintenance personnel

The number of maintenance personnel required depends on the operating tempo. Data on the direct maintenance man-hours (DMMH) expended during the Surge were not available. We do hold data on fleet experiences during lower-intensity operations and use that as a surrogate for the Surge data. Figure 37 shows the monthly O-level DMMH expended relative to the number of flight hours for all deployed F/A-18 squadrons over the past three years. Figure 38 shows similar data for I-level DMMH.[22] Superimposed on these data are regression lines, the slopes of which approximate the number of additional maintenance hours required per additional flight hour. In determining these lines we excluded data in the bottom ten-percentile for flight hours.

Also indicated in the figures is the number of flight hours used by the Aviation Supply Office to determine their wartime planning factors. We used this number of flight hours as the maximum number of flight hours that can be supported by squadrons manned to billets authorized (BA).

Using the Navy standard work week for military personnel afloat of sixty-seven hours (290 hours per month), we calculated from the deployment data the number of maintenance hours required per month for each additional 100 flight hours. In tables 28 and 29 we show the number of flight hours supportable with manning at BA, along with the expected number of DMMH that will be required to support that number of flight hours. We also show the number of DMMH needed to support each additional 100 flight hours and translate that into the number of additional maintenance personnel required. Since I-level maintenance is shared by all squadrons in the airwing, when using the values in table 28 to determine I-level manning, the number of expected flight hours should be for the entire airwing, not just a single squadron.

22. Data for other aircraft types are contained in appendix E (Volume 2).

Figure 37. Deployment data on F/A-18 O-level DMMH (per squadron)

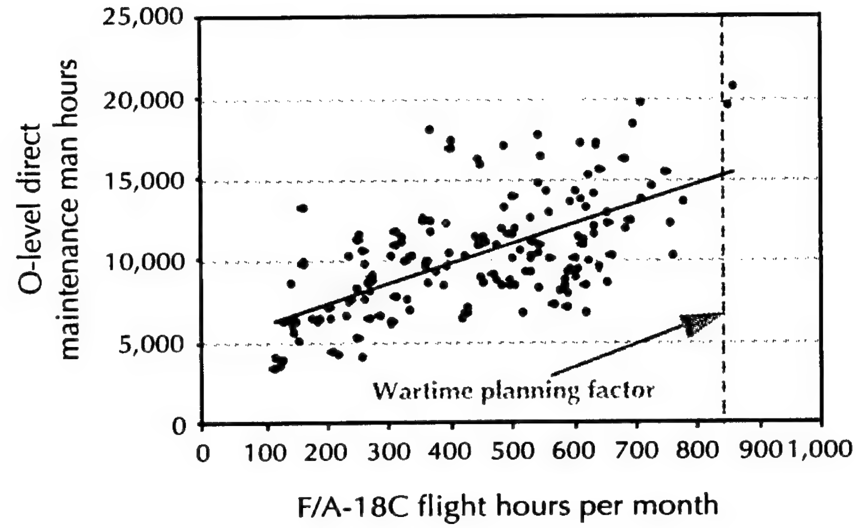


Figure 38. Deployment data on F/A-18C I-level DMMH (per squadron)

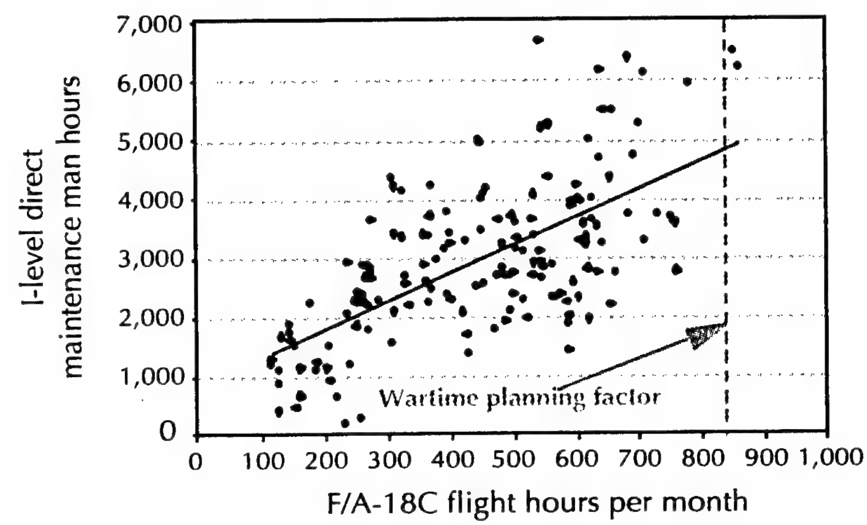


Table 28. Planning factors to determine O-level manning

Squadron	Wartime planning factor[a]: Flight hours supportable	Wartime planning factor[a]: O-level DMMH (hundred of hours)	Additional DMMH per additional 100 flight hours	Additional personnel per additional 100 flight hours
F-14A	1068	320	2130	7.3
F/A-18C	832	153	1230	4.2
EA-6B	300	143	1960	6.8
S-3B	700	185	1690	5.8
E-2C	341	100	950	3.3
ES-3A	200	30	740	2.6

a. Based on Aviation Supply Office data. Supportable by unaugmented airwing, manned at billets authorized.

Table 29. Planning factors to determine I-level manning

Squadron	Wartime planning factor[a]: Flight hours supportable	Wartime planning factor[a]: O-level DMMH (hundred of hours)	Additional DMMH per additional 100 flight hours	Additional personnel per additional 100 flight hours
F-14A	1068	135.0	10.8	3.7
F/A-18C	832	48.0	4.8	1.7
EA-6B	300	34.4	6.6	2.3
S-3B	700	63.1	6.3	2.2
E-2C	341	28.0	4.0	1.4
ES-3A	200	7.3	3.1	1.1

a. Based on Aviation Supply Office data. Supportable by unaugmented airwing, manned at billets authorized.

Figures 39 and 40 show how the required number of additional maintenance personnel varies with the number of flight hours exceeding the wartime planning levels. Note that the F-14 squadron needs proportionally far more DMMH per flight hour than any of the other squadrons. An example of how to use tables 28 and 29 to determine the required manning above BA follows.

Figure 39. O-level maintenance requirements

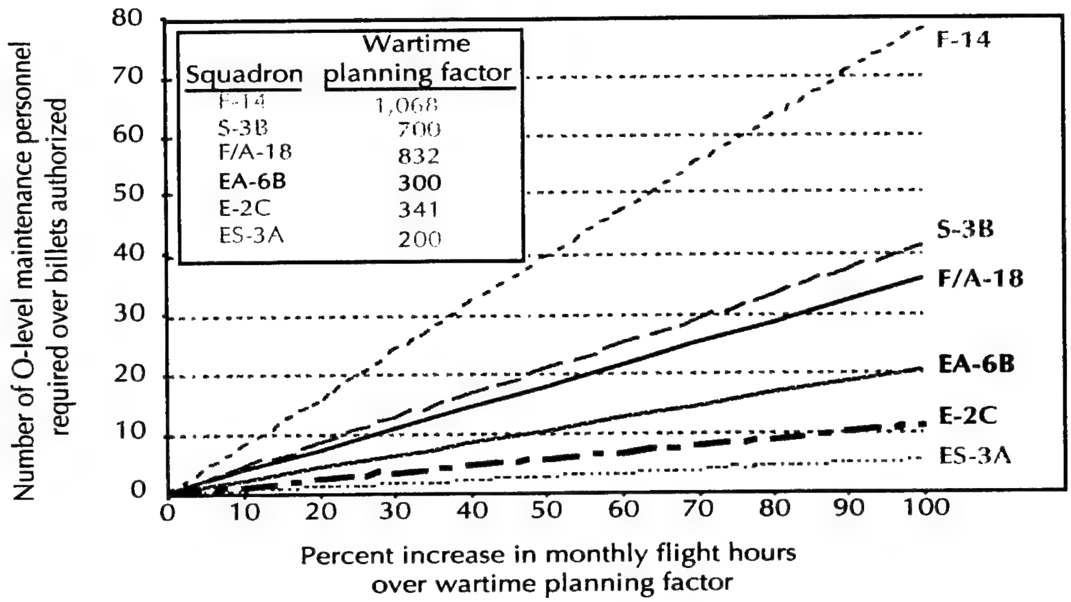
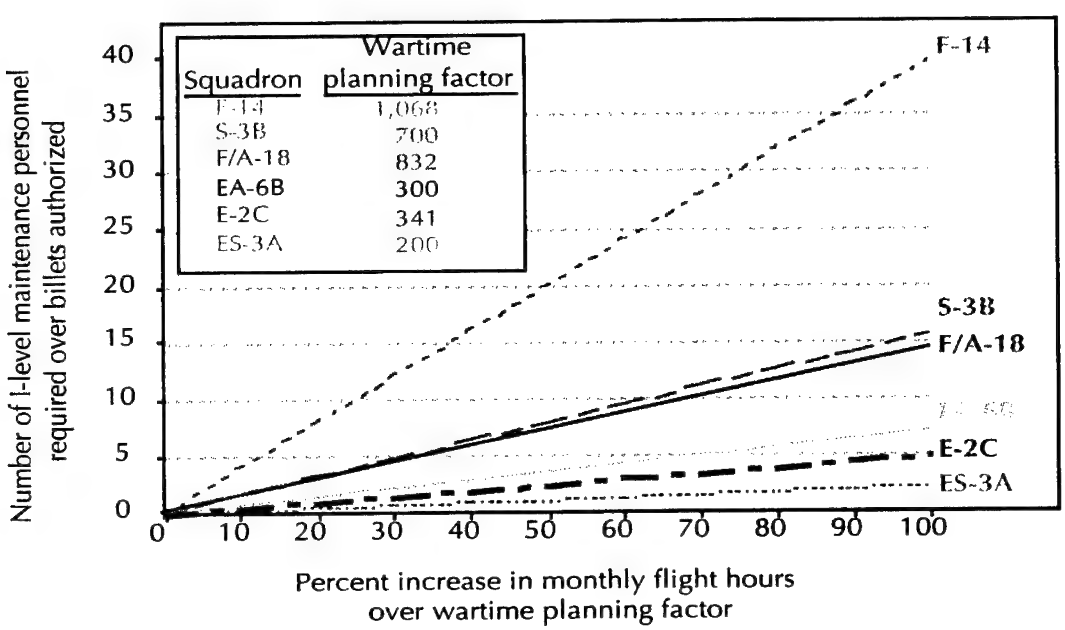


Figure 40. I-level maintenance requirements



Example of use

Let's estimate the additional maintenance personnel required to support an F/A-18C squadron planning to fly 1,000 flight hours per month. All other squadrons fly at their maximum supportable levels.

- The flight hours exceeding the "supportable flight hours" in table 28 is (1,000 - 832 =) 168 additional hours.
- Dividing the additional flight hours by 100 gives (168/100 =) 1.68 (this puts the flight hours into the units of the tables).
- Multiplying the additional flight hours by the additional personnel per 100 flight hours in table 28 (1.68 x 4.2 = 7.06) and rounding up to the nearest integer tells us that eight additional O-level maintenance personnel would be needed to support the higher operating tempo.
- The type of O-level maintenance personnel (i.e., machinists, mechanics, electricians, or electronics technicians) would be in proportion to the current representation in the squadron. In this example, this would mean an additional two machinists, two aviation electricians, four structural mechanics, and two electronics technicians.
- Applying the same method to determine the I-level manning tells us that three additional personnel are required.

Mission planners and analysts

Operational Strike Planning Cell

An Operational Strike Planning Cell (OSPC) stood up for the Surge to plan and coordinate strike missions. The cell was divided into two shifts, with five personnel each. Each shift was led by a senior reserve officer and included three active-duty pilots (two augmentees and one representative from CVW-9 staff) and one reservist. Each shift had a designated targeteer and an air intelligence specialist. They used enlisted personnel assigned to CVIC as needed; however, they would have preferred to have two to four dedicated enlisted personnel for support. Generally, they worked a 16-on/8-off schedule, although the OIC frequently worked longer than his scheduled shift.

Intelligence personnel

CVIC received four enlisted and four officer augmentees. The augmentees arrived on board USS *Nimitz* between 13 and 18 July. During the Surge, CVIC personnel worked with the OSPC to plan strike missions, prepare target folders, and conduct mission briefs and debriefs. Intelligence personnel typically worked a 12-on/12-off shift. With the high number of strike sorties came the need to debrief many missions and to process and summarize the debrief data. Even with their augmentation, CVIC was unable to conduct all their routine debriefing and reporting activities. In mid-Surge, priorities were re-evaluated and reporting requirements reduced. In addition, the CVIC OIC and assistant intelligence officers were not augmented and felt they could have benefited from additional manpower. Resident personnel reported no trouble with the integration of the augmentees into CVIC.

Strike Operations Center

Believing that the Strike Operations Center was to stand up as a level one JFACC during JTFEX and the Surge, the Strike Operations Officer had originally requested one Assistant Strike Operations Officer, four CTAPS operators, and a CTAPS Administrator. As it turned out, they never were JFACC, and the requested augment of CTAPS operators was reduced to two.

Ideally, all augmentees would come aboard fully qualified and additional training would not be required. This was not the case for the augmentees assigned to the Strike Operations Center. The augmentee CTAPS operators were inexperienced, and there was a significant learning curve associated with incorporating of the augmentees into *Nimitz*'s Strike Operations Center and CVW-9's JAOC. Reservists, especially those with little or no experience with carrier operations and/or JFACC procedures, were the most difficult to incorporate. Providing this training was time-consuming for the resident personnel. These personnel feel a minimum of two weeks, during low-intensity operations, should be allotted for training and orientation for CTAPS operators who do not have experience in operating on a carrier or with JFACC procedures.

In contrast, the ARG/MEU supplied the Strike Operations Center with a specially qualified liaison officer who proved extremely valuable. This officer proved to be a critical in coordinating with the ARG/MEU and in understanding how the *Nimitz* battle group could support ARG/MEU operations.

Controllers

The Air Operations department was augmented with four PQS-qualified air traffic controllers and an Assistant Case III qualified Air Operations Officer. With the augmentation, they were able to create a second watch team. Each team was composed of eighteen personnel:

- Five supervisory personnel
- Thirteen workers
  - — Six console operators
  - — Five status board keepers
  - — Two plotters/record keepers.

In addition, there were five administrators to support the two teams.

Each team worked a 12-on/12-off schedule. This work schedule was based on typical requirements during Case III weather and a nominal ten aircraft launch/recoveries per hour. During normal flight operations, Air Operations mans a single team that works a 16-on/8-off schedule. So the Surge required fewer work hours per person than normal operations and allowed individuals to receive more rest than during normal flight operations. However, to conduct continuous flight operations, the level of manning was necessary.

Integration of augmentees

At all levels, we found the key to augmentee integration with the resident personnel was the establishment of trust and rapport between the residents and the augmentees. For some jobs—such as ordnance-loading—it was relatively easy and quick for the augmentees to establish their competence. In general this was the case for jobs where

physical activities were paramount. As the complexity of the job and the potential for causing injury to others increased, it was more difficult for the augmentees to establish themselves quickly.

In the extreme, we have the case of the V-2 division, which by foregoing augmentation, declined even giving augmentees a chance to prove themselves. A major impediment to incorporating augmentees to the V-2 division is qualifying individuals to work on the flight deck. Personnel Qualification Standards (PQS) require four days and nights of observation for flight deck qualification. In operational situations in which warning time is not sufficient for augmentees to arrive on board and become flight deck qualified, qualified augmentees must be chosen. Even then, the augmentees must gain the confidence and trust of their co-workers.

Similarly, CAG Gunner felt the time spent integrating the augmentees to the ordnance loading crews was essential. Some of these augmentees had no flight deck experience and time was needed to get them flight deck qualified.

Another example is provided by the OSPC, who were initially held at arms length, until they were able to prove their worth to the strike leaders. Indeed, there were a few strike leaders who did not embrace the OSPC. For these few, the OSPC was a hinderance more than a help, for they dismissed the OSPC's products and conducted their own strike planning. Integration of the OSPC into the airwing operations was delayed due to a lack of clearly articulated operating procedures that had the endorsement of the airwing, CVIC, and the OSPC. Reflecting the frustrations of the entire OSPC, one member remarked that the "concept was not fully explained to CAG, N-2, or myself before JTFEX. We all sort of figured things out as we went along." If the OSPC concept is to be implemented in future fleet operations, as we strongly recommend, guidelines for procedures and delineation of responsibilities must be established early, preferably long before the first strike sorties launch.[23]

23. We understand NSAWC is preparing an OSPC mission statement for inclusion in the NSAWC Airwing TACMEMO.

Some groups seemed to flow easily into the overall operation. Upon examination, these groups either worked in an area in which it was easy to prove their prowess—such as the maintenance crews or bomb loaders—or they benefited from previously recognized reputations within their communities and the community operated under a cohesive umbrella of procedures—such was the case of the aircrews. Often cited by the aircrews was the strike execution guidance and training provided by NSAWC that allowed aircrews to quickly integrate into the airwing operations.

We also had the example of where the lack of uniform procedures hindered operations—the lack of cohesiveness between the Air Boss and Mini Boss and their augmentees. The Air Boss and Mini Boss were provided augmentation since no other appropriately qualified personnel were resident on board. The augmentees allowed the Air Boss and Mini Boss to receive adequate rest, but difficulties arose when the augmentees held different interpretations of procedures regarding the movement of aircraft on the flight deck and between the flight deck and hangar bays. As a result, there were delays in the movement of aircraft, including missed opportunities for running the deck-edge elevators that resulted in strike sorties being missed. Flight deck crews expressed frustration over having to operate under apparently different sets of procedures that changed frequently.

In contrast, the Air Operations Officer was also provided an augmentee since no other appropriately qualified personnel were resident on board. The Air Operations Officer and his augmentee agreed upon procedures before the Surge began. They had the added advantage of having worked together previously. For them, the operation worked smoothly and their workers could focus on their jobs.

Command fatigue

Prolonged high-intensity operations require strong and continuous command presence. Yet, despite their best efforts to counteract fatigue, individuals in command will grow tired and need rest. Some individuals may be tempted to ignore or deny their own physical need for rest, potentially impairing their good sense and judgment.

So individuals in command must receive rest and someone must be designated to act in their stead during their rest periods. The need to establish trust is no different than what we discussed above, only in this case, it is far more difficult for a stranger to establish a trust relationship quickly. Because the establishment of trust is so very critical in these positions and difficult to achieve, we recommend that, in general, individuals in positions of authority choose a person from the resident staff to whom to delegate their authority. This has the advantage that the chosen delegate can learn the individual in command's approach to problems and rationale for decision-making.

Indeed, this is what individuals in positions of authority by-in-large elected to do during the Surge (table 27). However, without additional help, this added significantly to the delegates' task-loading and some tasks went undone. The person chosen to act for the individual in command does have a normal job on board. We recommend, therefore, that augmentation be provided to assist the delegates.

Firepower capacity

Planning for the Surge used a benchmark of 200 strike sorties a day for four days. The duration of the Surge was chosen to lie within the three- to five-day goal set in [14]. The number of strike sorties was derived from operator intuition gleaned from experiences with lower operating tempos, historical aircraft availability, and consideration of pilot utilization limits. USS *Nimitz* and CVW-9 came close to achieving this benchmark. In hindsight, we can identify opportunities where USS *Nimitz* and CVW-9 could have surpassed the benchmark.

To determine the limits to operating tempo, we focused on the three building blocks of sortie generation—pilot utilization rate limits, aircraft availability (airframe) limits, and the flight deck crews' ability to ready aircraft for launch. We have four primary findings from our analysis:

- Had USS *Nimitz* and CVW-9 pursued a more aggressive sparing policy, they could have generated 801 strike sorties over the four-day Surge.
- USS *Nimitz* and CVW-9 had the capacity to generate an additional 50 to 100 strike sorties over the four-day Surge—however, these estimates are easy to generate on paper but difficult to achieve in practice.
- Had the Surge MAAP called for a higher operating tempo, the limiting factor to sortie generation would have been the ability to ready strike aircraft for launch.
- The Surge operating tempo could have continued for an additional twelve to twenty-four hours. We base this finding on several factors: the rates of expenditure of weapons and JP-5, aircraft availability, the need to conduct scheduled maintenance on ship and aircraft systems, and personnel fatigue.

Sparing policy

We described the sparing policy implemented in the Surge in the *Operations during the Surge* section of this report. In summary, had all spares been manned as Super Spares, seven strike sorties that were missed could have been saved. Had each event been manned with a Super Spare, an additional twenty-three sorties could have been saved. With a more aggressive sparing policy, USS *Nimitz* and CVW-9 could have generated 801 strike sorties (and a total of 1,005 sorties).

Sparing comes with costs. Pilot utilization rates increase and aircraft must undergo servicing (although not as extensive a procedure as is required after a flight). Figure 50 (on page 134) provides a nomogram for determining the effect of sparing on strike/fighter pilot utilization rate. At the deployment level of manning, the sortie generation seen during the Surge would not have been possible. However, at pilot manning levels of the Surge, USS *Nimitz* and CVW-9 could have manned spares on all events. With 101 strike/fighter pilots on board USS *Nimitz*, sparing each event would have increased the pilot utilization rate from 2.1 to 2.2—still under the 2.5 cap set by Commander, Carrier Group Seven.

Airframe limits on sortie generation

We estimated the number of sorties that could have been generated by Carrier Airwing Nine aircraft during Surge in two ways. The first looks at the number of MC aircraft on the flight deck event by event. This couples the aircraft MC rates with the allocation of aircraft between the flight and hangar decks. The second uses simulation modeling of aircraft availability to estimate by airframe type the likelihood of generating a specific number of sorties.

Estimates based on MC aircraft on the flight deck

We recorded the number of aircraft on the flight deck and whether those aircraft were MC or NMC fifteen minutes before the next launch. For the MC aircraft, we recorded whether they were scheduled for the next launch. For the S-3B, we counted the alerts as MC and scheduled. Table 30 shows the average number of aircraft on the

flight deck; in appendix C (Volume 2), we provide the data collected on availability of strike/fighter, EA-6B, and S-3B aircraft.

Table 30. Aircraft on the flight deck and their status

	Average number of aircraft on flight deck			
Aircraft status	F-14A	F/A-18C	EA-6B	S-3B
MC aircraft				
Scheduled	1.5	4.9	0.6	1.3
Not scheduled	0.9	2.2	0.6	1.8
NMC aircraft	2.1	1.6	0.2	0.7
Total	4.5	8.7	1.4	3.8

Figure 41 shows the relationship between F/A-18 availability (MC aircraft on the flight deck—upper line) and the air plan's mission requirements (lower line). Figure 42 shows a similar plot for the F-14. Where the lines cross on these figures indicates that not enough MC aircraft were on the flight deck to meet the scheduled demand and, consequently, sorties were missed. By in large, the number of available strike/fighters exceeded the requirement.

Figure 41. F/A-18 availability (composite of all squadrons) versus requirement

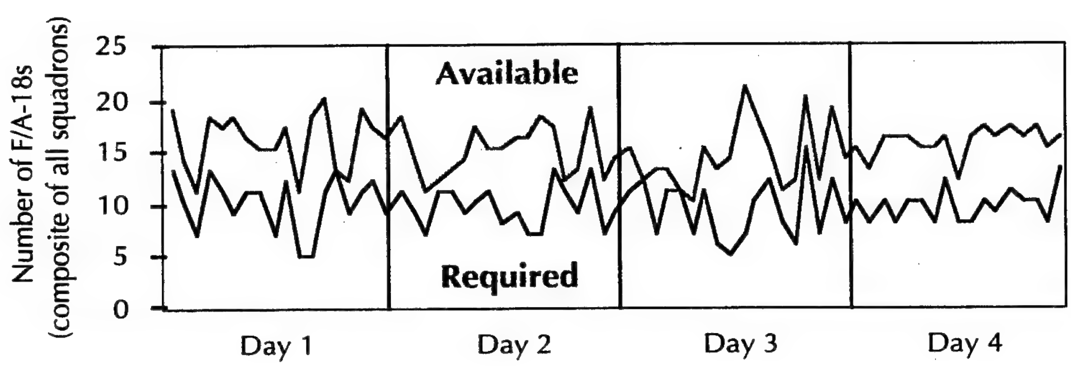
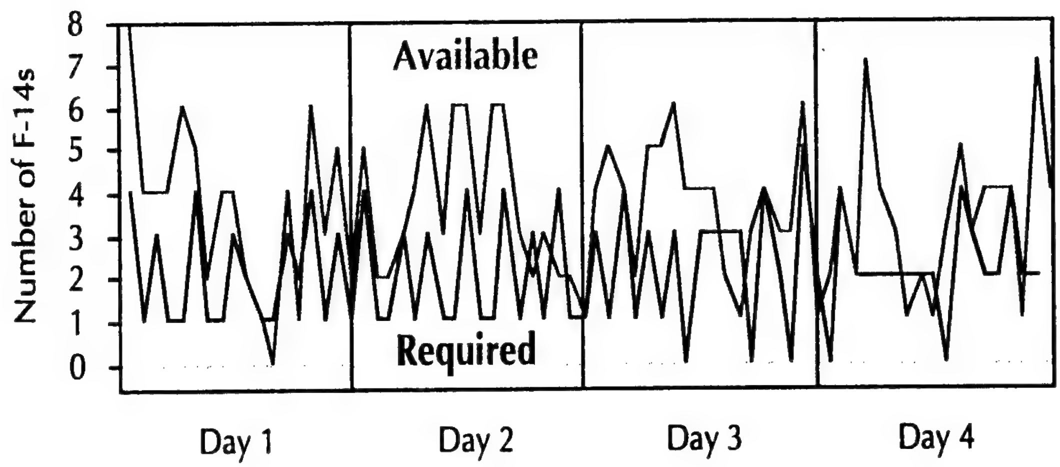


Figure 42. F-14 availability versus requirements



For the sixty-five events for which we hold data, MC F/A-18s were on the flight deck and not scheduled for the next launch 138 times; MC F-14s were on the flight deck and not scheduled for the next launch in fifty-seven times. These numbers exceed the possible number of additional sorties. For example, if a MC aircraft is on the flight deck over two cycles, it contributes two to the count. If, however, the aircraft had flown on the first cycle, it would not have been available to be flown on the second event. Accounting for this possibility, the number of additional launch opportunities for the F/A-18s is between 78 and 138, and between 44 and 57 for the F-14s. Had these launch opportunities been realized, the F/A-18s would have averaged between 20.0 and 21.7 sorties per airframe and the F-14s would have averaged between 13.5 and 14.4 sorties per airframe. These airframe utilization rates are near the averages predicted by our simulation models [8, 9].

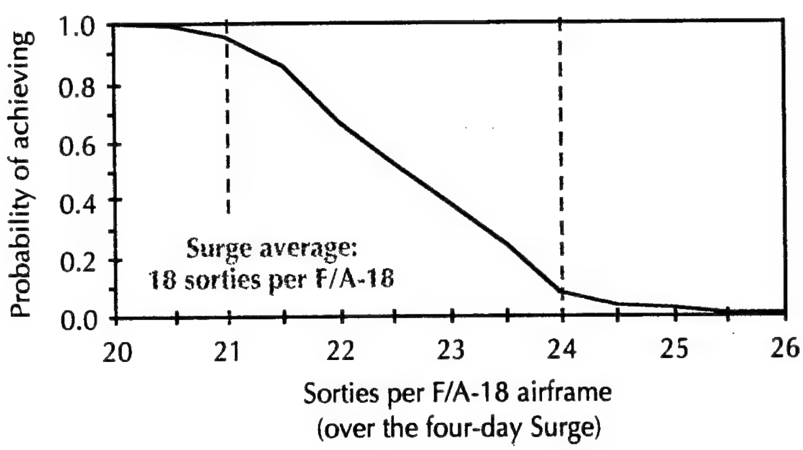
Simulation modeling of airframe limits

We used simulation modeling [8, 9] to estimate airframe sortie generation capacity. The model estimates are optimistic. The model considers only repairs stemming from normal flight of the aircraft. In particular, maintenance actions stemming from accidents on the flight or hangar decks (*crunches*) or from combat are not considered.

The model assumes all aircraft of the same type are on the flight deck; however, in reality some aircraft will be in the hangar bay and an elevator move is required to bring them to the flight deck for use.

For this simulation, we used the *Nimitz* MAAP to specify the operational requirement (but with an increased operating tempo) and an extensive database on fleet aircraft maintenance data [8, 9] to estimate airframe sortie capacity. Individual observed performances should be expected to vary (both above and below) the model's estimates of average sortie generation capacity. Figure 43 shows the probability that thirty-six F/A-18s should be able to average a given number of sorties per airframe over the four-day Surge. Each F/A-18 airframe should be expected to average between twenty-two and twenty-three sorties over the four days of Surge. In future Surge operations under similar requirements, the limit to sortie generation imposed by the F/A-18 should be between twenty-one and twenty-four sorties per airframe.

Figure 43. F/A-18 airframe capacity (simulation modeling)[a]



a. Thirty-six F/A-18s on board.

The model's predictions are higher than the F/A-18 utilization rates seen during the *Nimitz* Surge. We expected this for two reasons: the model estimates the most that the airframe can achieve; and the

model does not incorporate limitations imposed by aircrew availability or aircraft turnaround, or choices as to the number of MC aircraft left in the hangar bay.

The model's predictions and the observed data corroborate each other—both indicate that there were always more MC F/A-18s than the *Nimitz* MAAP demanded. The modeling indicates that what we observed during the Surge was not a fluke. Indeed, airframes should not be a limit to sortie generation under similar circumstances.

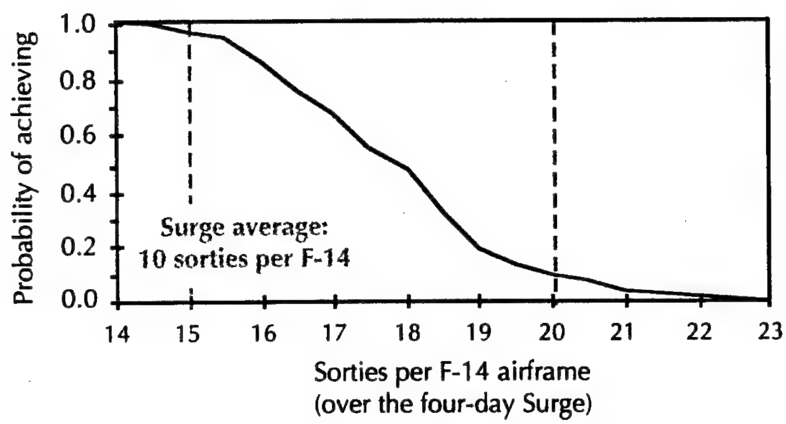
Figure 44 shows the same analysis for the F-14. The simulation indicates that the number of sorties by each F-14 airframe should be between fifteen and twenty, with an average of between seventeen and eighteen sorties. This capacity is significantly higher than what was evidenced during the *Nimitz* Surge. Unlike the F/A-18s, however, the F-14s frequently were hard pressed to meet the demands of the Surge flight schedule. The historical AV3M data of the F-14A used in the simulation modeling are based on deployments in the 1980s and early 1990s. The F-14A is an aging airframe and these data may no longer be representative of current deployed F-14As. As a result, our assessment of the sortie generation potential of the F-14A may be optimistic. On the other hand, as we discussed in the *Maintenance and Supply* section, the MC rates of the F-14 squadron were significantly lower than other deployed F-14A squadrons in the eighteen months before the Surge. It could be that the F-14A experience during the Surge was merely unfortunate.

Our model also indicates that five to nine fewer F/A-18s and three to five fewer F-14s could have generated the 643 F/A-18 and 145 F-14 sorties during the Surge. Because the model does not consider flight or hangar deck *crunches*, these excess aircraft can be viewed as insurance against such accidents. These excess aircraft can also serve as insurance against loss of an aircraft in flight—from a mishap or combat loss. Indeed, a loss rate of 0.0075 would have resulted in requiring all thirty-six F/A-18s to be present to achieve the same sortie total.

The model results predict that CVW-9 operated well below F/A-18 and F-14 limits. Any airwing planning a similar operation should feel

confident that F/A-18 and F-14 aircraft availability would not be the limiting factor in meeting a similar schedule.

Figure 44. F-14 airframe capacity (simulation modeling)[a]



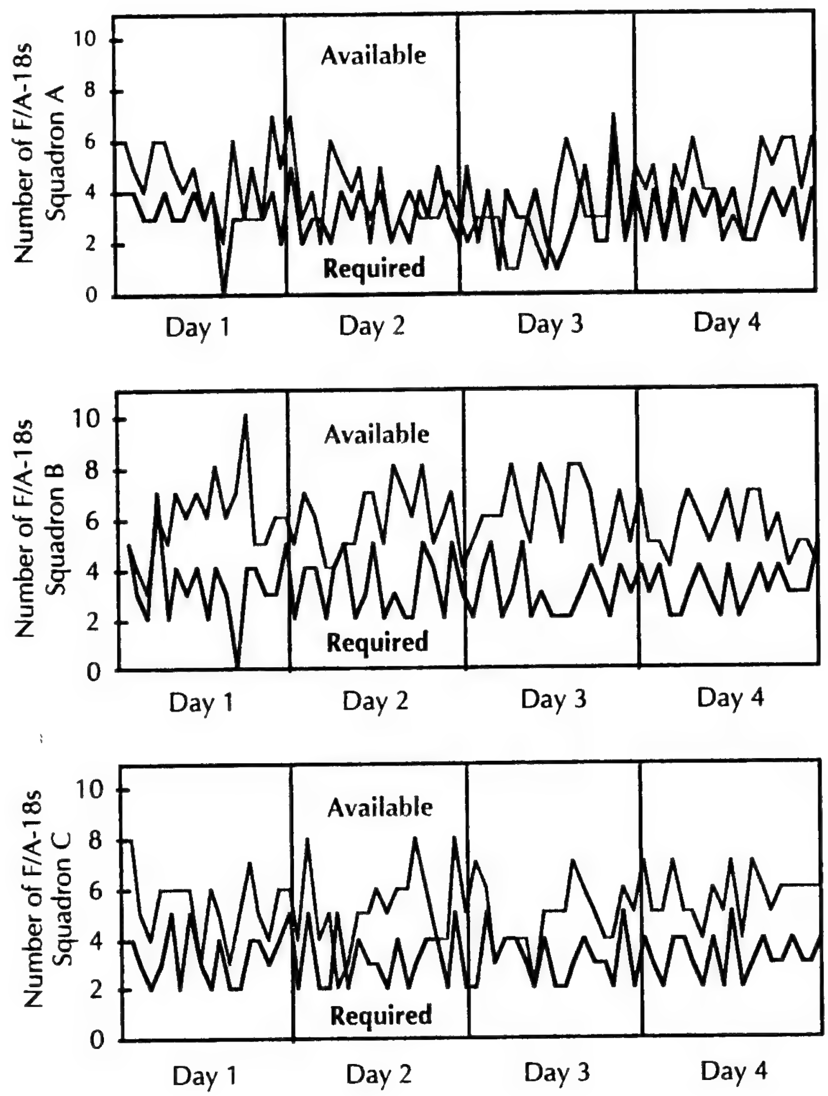
a. Fourteen F-14s on board.

Aircraft pooling options

In the above analyses, the F/A-18s were treated as a pooled asset—there was a single source of aircraft for meeting the schedule requirements. In fleet operations, F/A-18s are grouped into three squadrons each with their own command structure, pilots, maintenance personnel, and ordnance-loading crews. The *Nimitz* MAAP placed equal demands on the three F/A-18 squadrons. Unfortunately, one of the F/A-18 squadrons experienced low MC rates during the Surge, which illustrates that aircraft availability is not always uniform across all squadrons. Indeed, this is more the norm than the exception.

As figure 45 shows, when the F/A-18s are viewed in the aggregate, the number of F/A-18s was always sufficient to meet the launch requirements. Yet, a few launches were missed due to lack of MC F/A-18s from specific squadrons. Figure 45 shows F/A-18 availability versus requirements by squadron—a different picture than that of figure 41.

Figure 45. F/A-18 availability versus requirements by squadron[a]



a. The number of MC aircraft on the flight deck was insufficient to meet the air plan requirements at those times when the "available" and "required" curves cross.

F/A-18 Squadron A—the one with the lowest readiness—clearly had trouble making the air plan schedule. In fact, all three F/A-18 squadrons exhibited at least one time where there weren't enough MC aircraft on the flight deck to satisfy the imminent launch's requirements. Only when F/A-18 aircraft are pooled—as in figure

41—are there sufficient aircraft available to always meet the mission tasking.

Carrier Airwing Nine leaders recognized the benefit of sharing aircraft among F/A-18 squadrons. By CAG's direction, and with the approval of squadron commanding officers, in a few instances pilots from one F/A-18 squadron flew aircraft provided by the other two F/A-18 squadrons. A *super team* of maintenance personnel from the three squadrons was formed to repair the ailing squadron's aircraft. Within a few hours, the ailing squadron's aircraft had a MC rate comparable to its sister squadrons. This demonstrated that sharing can occur with coordination from the airwing staff and significant benefits can be realized.

To implement pooling procedures, protocols must be established. For example, responsibility for the maintenance, parts, fuel, and turnaround of the shared aircraft have to be clearly articulated. Protocols should address the conditions under which the aircraft would return to its original squadron and whether or not the aircraft was a candidate for cannibalization. These protocols need to be in place and agreed upon by all parties well in advance of implementation.

Pilot limits on sortie generation

The appropriate upper bound for pilot utility rate[24] depends on the stress and workload intrinsic to the execution of the mission, along with consideration of the non-flying tasking of the aircrews. There are some official guidelines and historical wartime data on pilot utilization rates. OPNAV Instruction 3710.7P [15] states that "daily flight time should not normally exceed three flights or 6-1/2 total hours flight time for flight personnel of single-piloted aircraft," but adds the caveat that this restriction can be waived by the operational commander. No mention is made of the types of missions that could be flown. During the Vietnam conflict, pilots were allowed to fly at most two combat and one non-combat sortie each day [16]. The *Nimitz*

24. Pilot utilization rates are based on the number of man-ups per day which, in general, will exceed the number of sorties.

MAAP called for virtually all strike/fighter sorties to simulate combat missions. Commander, Carrier Group Seven specified a maximum aircrew utilization rate of 2.5. For real-world operations, the limit set by the operational commander may be higher or lower than this, depending upon the circumstances he faces.

Using Commander, Carrier Group Seven's limit and the number of pilots per squadron (including the augmentees), the maximum number of F-14 and F/A-18 man-ups is 220 and 790, respectively. This finding bounds the number of strike/fighter sorties to under 1,010. As discussed earlier, F-14 aircrews manned aircraft 183 times and F/A-18 pilots manned their aircraft 660 times. Under the limit imposed by CCG-7, the potential existed to man F-14s an additional thirty-seven times and to man F/A-18s an additional 130 times. At the sortie-to-man-up ratio demonstrated during the Surge, this could have resulted in twenty-nine additional F-14 sorties and 126 additional F/A-18 sorties (for a total of 943 strike sorties). Another use for these excess man-ups could have been to increase the number of spares manned, which could have cost thirty-six man-ups but potentially increased the number of strike sorties by twenty-three.

We consider next whether aircrew could have flown at rates higher than the 2.5 limit. Our analysis is based on an assessment of the average time required to complete a mission.

Aircrew turnaround

Just as for aircraft, time is needed to turn around aircrews between events. Aircrews require time both before a scheduled sortie (to prepare for the mission) and following a sortie (for various debriefings). Figure 46 depicts the flow of events before and after a typical sortie. Table 31 provides nominal estimates for typical times to complete turnover events based on aircrew experience and analyst observations. Using this information, we estimated that the time to man-up an aircraft that does not fly is between forty minutes and three hours. To man-up and fly a mission consumes, in addition to the flight time, between 1:30 and 4:15.

Figure 46. Aircrew turnaround activities

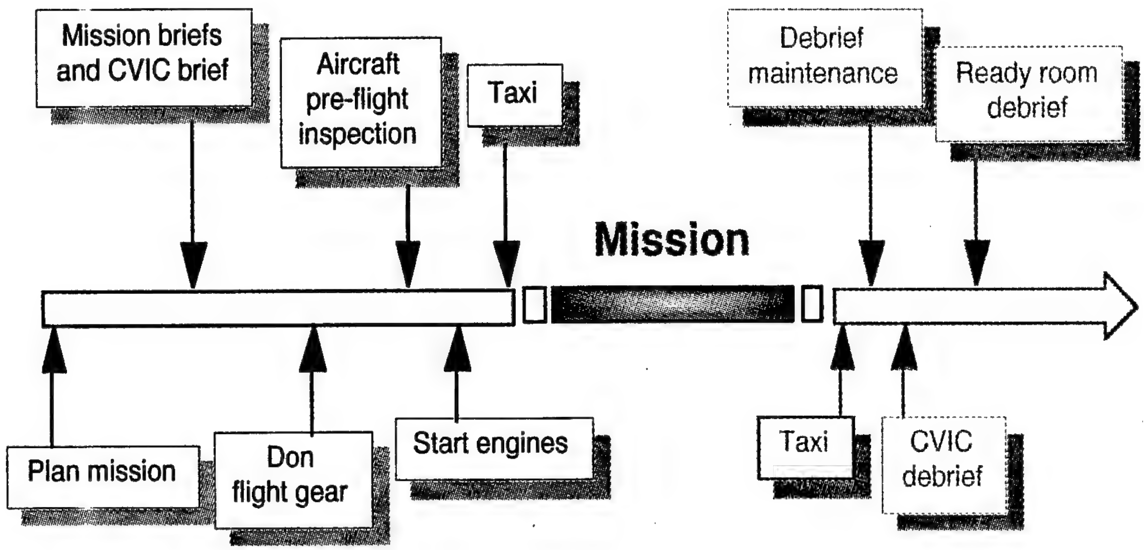


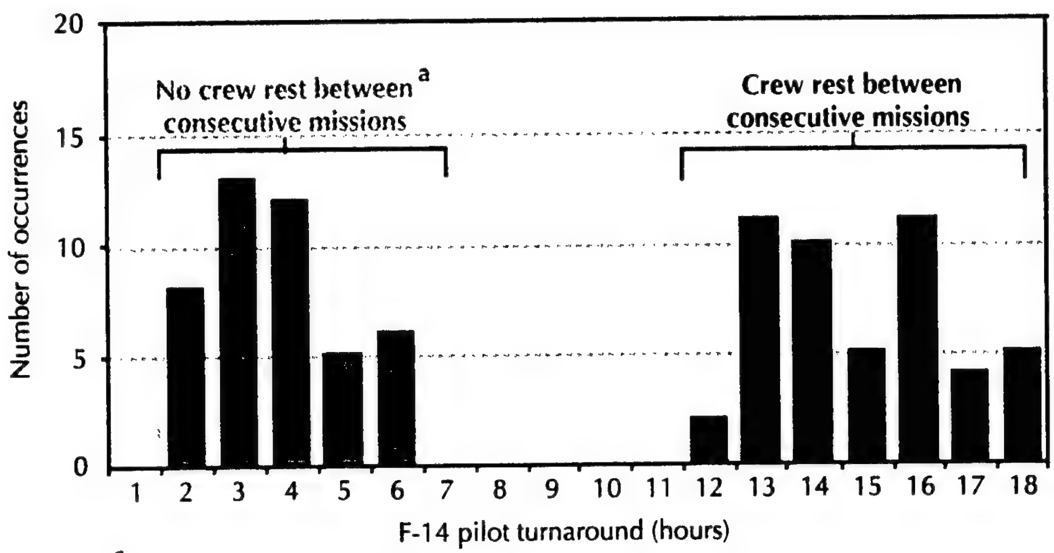
Table 31. Time to complete aircrew turnaround activities

	Duration (hrs:min)	
	Minimum	Typical
Pre-launch activities		
Mission planning[a]	0:00	1:00
Mission briefs	0:15	1:00
Don flight gear	0:00	0:15
Preflight inspection of aircraft	0:15	0:15
Start and taxi	0:10	0:30
Total pre-launch time	0:40	3:00
Post-recovery activities		
Recover flight and taxi	0:15	0:15
Debrief maintenance	0:15	0:15
CVIC debrief	0:05	0:15
Mission debriefs (ready room)	0:15	0:30
Total time required	1:30	4:15

a. The presence of the Operational Strike Planning Cell greatly eased the workload of the strike leaders, and as a result, reduced the amount of time the strike leaders spent planning missions and preparing the mission briefs.

To verify that our overall estimate of the time required was reasonable, we calculated the time available to strike/fighter pilots between consecutive flights. Figures 47 and 48 show the results for F-14 and F/A-18, respectively. Time between consecutive flights should be longer than the time required for pilot turnaround.

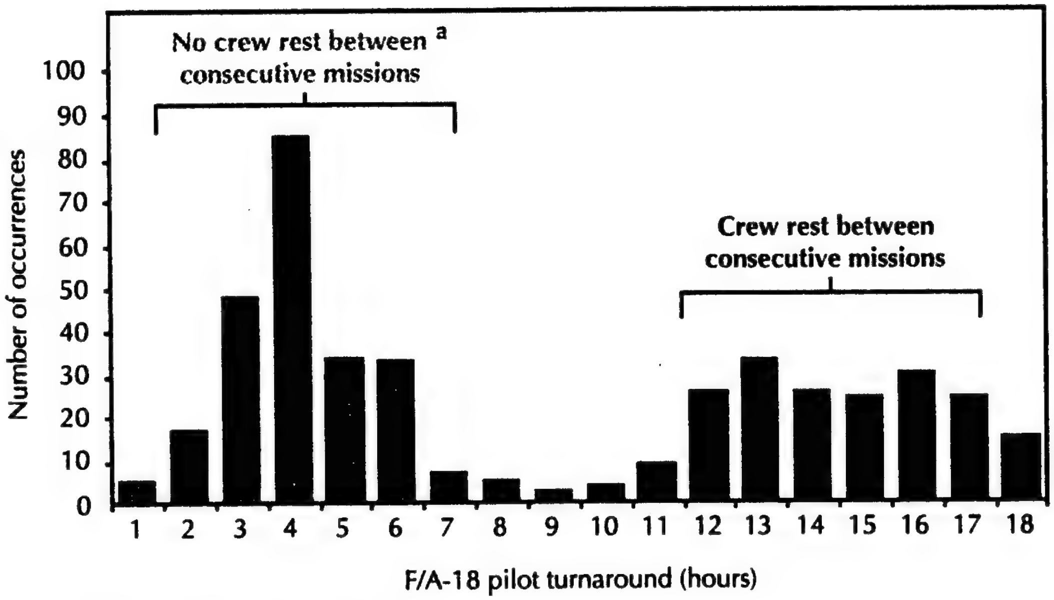
Figure 47. F-14 pilot time for turnaround



[a] *Average turnaround time for consecutive sorties = 3:15*

As figure 48 shows, in several instances (about twenty) F/A-18 pilots flew consecutive missions with two hours or less for turnaround. These pilots would recover, and then fly on the next event to the same target area, getting mission updates in the cockpit. In the bulk of instances, however, strike/fighter pilots had more than sufficient time on board USS *Nimitz* to devote the 1:30 to 4:15 we estimate is required for turnaround.

Figure 48. F/A-18 pilot time for turnaround



[a] *Average turnaround time for consecutive sorties = 3:45*

Aircrew utilization limits

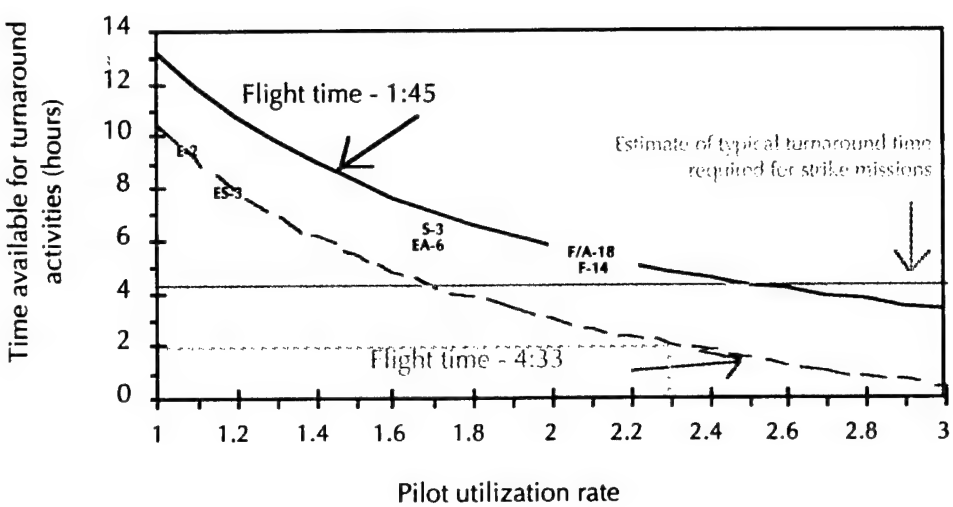
The time dedicated to each sortie is the sum of the turnaround time and the flight time. The flight time will, of course, vary by aircraft type and by assigned mission. Table 32 gives the average flight time, typical cycle multiples, and the missions flown for each aircraft type during the Surge.

Table 32. Average flight times and missions flown during Surge

Aircraft type	Average flight time (hr:min)	Cycle multiple	Missions
F-14	2:04	1-2	AI, ASR, CAS, DCA, OCA, TARPS
F/A-18	1:45	1-2	AI, ASR, CAS, DCA, INT
EA-6B	2:22	2	SEAD
S-3B	2:15	1-2	AI, ASR, MTNK, RTNK
ES-3A	4:33	3-4	ESM
E-2C	4:01	2-3	AEW

Allowing nine hours for crew rest leaves fifteen hours available for work. Figure 49 shows the relationship between pilot utilization rate and the time allowed for pilot turnaround. In this figure we graph curves corresponding to flight times of 1:45 and 4:33, which bound those of the Surge. Indicated on the figure are the times available during the Surge for pilot turnaround by aviation community. The F-14 pilots had the least amount of time between manning of aircraft—on average just a little over five hours. Since this time is close to our estimate of the typical turnaround time required for strike missions, this indicates that the number of F-14 pilots, while adequate, was close to limiting the number of sorties they could generate. All aviation communities, however, lie above our estimate for the typical time required for pilot turnaround. This finding suggests some excess capacity in the number of aircrews available.

Figure 49. Pilot utilization rates, pilot turnaround time, and flight time



Lowering the typical pilot turnaround time can dramatically increase the bound on pilot utilization. Figure 49 can be used to determine this increase. For example, if you determine that the ES-3 crews require 4:15 to prepare and debrief each mission, the maximum pilot

utilization rate that could be attained is 1.7. If preparation and debrief time can be reduced to two hours, the maximum utilization rate can be increased to 2.3. This nomogram does not incorporate the stress of flying combat missions and should be used only as a supplemental planning aid.

Even if the pilot utilization rate remains unchanged, lowering the turnaround time will increase the time available for crew rest and reduce fatigue. Of all the pilot turnaround activities listed earlier, the time spent in mission planning is the easiest to reduce. Indeed, this demonstrates one potential benefit of the Operational Strike Planning Cell—by reducing the time strike leaders spent in CVIC, the OSPC significantly increased the number of strike missions that could be executed and reduced pilot fatigue.

Had pilots manned the number of aircraft so as to have spent all their work hours preparing for missions, flying, or debriefing, the pilot utilization rates shown in table 33 would have been achieved. The F-14 pilot utilization rate is higher than that of the F/A-18 because the ratio of F-14 sorties flown to the number of F-14 man-ups (0.79) is significantly lower than that for the F/A-18 (0.97). This difference is a reflection of intrinsic differences in CVW-9's assumptions of the reliability of the two aircraft. At the ratio of man-ups to sorties flown demonstrated during the Surge, the pilot utilization rates listed in table 33 would have limited the sortie generation of the F-14 and F/A-18 to 188 (43 additional) and 769 (126 additional) sorties, respectively.

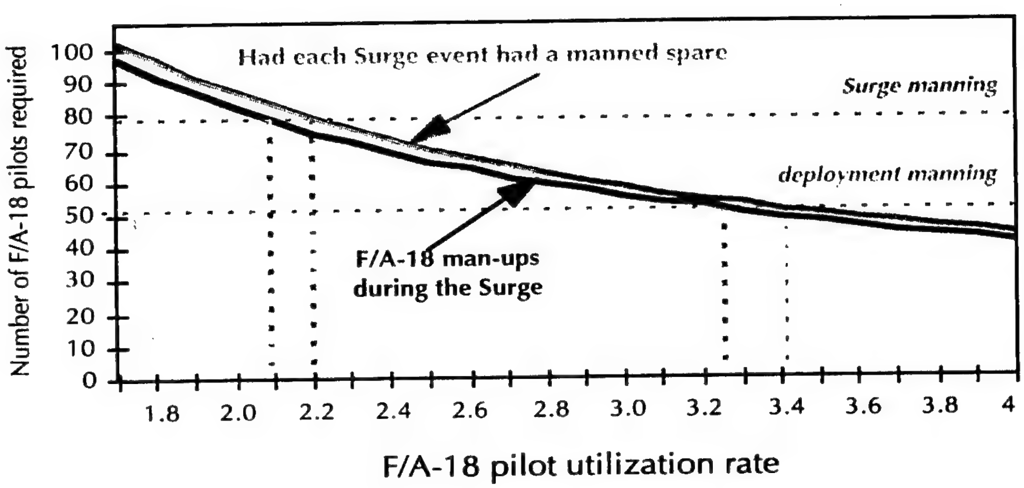
Table 33. Pilot utilization limits

	Pilot utilization rates	
Aircraft type	Maximum possible[a]	Realized in the Surge
F-14A	2.7	2.1
F/A-18C	2.5	2.1
EA-6B	2.3	1.7
S-3B	2.3	1.7
ES-3A	1.7	1.2
E-2C	1.8	1.1

a. Based on average mission times flown during the Surge, the ratio of sorties flown to man-ups, and an average of 4:15 for pre- and post-flight activities.

We can translate the rates shown in table 33 into minimum pilot complements: seventeen for the F-14A squadron; twenty-two for each of the F/A-18C squadrons; six for the EA-6B squadron; ten for the S-3B squadron; four for the E-2C squadron; and three for the ES-3A squadron. Of course, additional pilots serve as a cushion against combat losses or unforeseen circumstances that might reduce the number of available aircrews. Figure 50 shows the relationship among pilot utilization rate, and number of pilots available at the Surge operating tempo. Also shown is the impact had CVW-9 manned each event with a Super Spare.

Figure 50. Pilot utilization rates, pilots available, and manning of spares



The rates shown in table 33 bound that which is possible to achieve. The computation assumed a maximum packing of missions into the work day; such efficiencies are easy to achieve on paper, but almost impossible in practice. Secondly, not all squadron pilots will be available for flight duty at all times. For example, some pilots will be standing watch, SIQ, or TAD. Reference [3] estimates ten percent of the pilots' time is consumed by non-flying duties.[25] To illustrate the

25. During the Surge, squadron pilots were relieved of all non-flying duties including LSO, SDO, and LNO responsibilities.

impact of requiring pilots to perform non-flying duties, table 34 shows our estimates of the number of man-ups possible taking this ten percent loss into account. Even with this degradation, all squadrons showed the potential for additional man-ups per day. This finding agrees with our assessment that the CVW-9 aircrews—with augmentation—were not pushed to their limits in the Surge.

The mission drives the MAAP and the number of sorties required. In a joint operation, coordination through the ATO process is required to fly additional sorties over what is specified in the ATO. One potential use for the excess pilot man-ups is to man spares. While manning spares increases pilot utilization rates, in this instance, USS *Nimitz* and CVW-9 could afford the cost. As we have commented before, had spares been in place on all events and used when needed, thirty additional strike sorties might have been flown at the cost of thirty-six additional strike/fighter man-ups.

Table 34. Estimates of aircrews' excess capacity during the Surge

	Aircrews	Man-ups in the four-day Surge		Excess man-up capacity	
Aircraft	on board	Capacity	Demonstrated	only flying duties[a]	with non-flying duties[b]
F-14A	22	237	183	54	30
F/A-18C	79	790	660	130	51
EA-6B	7	64	48	16	9
S-3B	12	110	84[c]	26	15
ES-3A	4	27	16	11	8
E-2C	6	43	28	15	10

a. Obtained by subtracting the number of demonstrated man-ups from the computed capacity for man-ups.

b. We assumed ten percent of aircrews' work day required for watchstanding and medical down time, and include sorties flown, deck aborts, and man-ups for spares.

c. Only S-3 man-ups by squadron personnel are shown. Additional man-ups were made by non-squadron personnel.

Turnaround limits on sortie generation

We turn now to limits on sortie generation imposed by the need to ready aircraft for launch. Turnaround functions include fueling, ordnance loading, respotting, and servicing. Some of these functions cannot be performed simultaneously, and procedures vary with

aircraft type in some cases. Turnaround functions are performed by a limited number of flight deck crews, so some queuing of aircraft frequently occurs.

We focused on the turn around of strike/fighters because these aircraft took the longest to ready for launch (requirement to load ordnance) and generated the majority of sorties. We approached the assessment of turnaround limits in two steps. First, we used observations on the time required to complete individual turnaround functions and coupled this with the order in which these functions typically are conducted to arrive at estimates of the typical time required to ready strike/fighters for launch. We translated this into the number of strike/fighters that could be turned within a cycle and, ultimately, throughout the four-day Surge. In the second step, we examined each event to determine whether there were MC strike/fighters on the flight deck as candidates to ready for launch. The first step estimates what might have been possible, independent of how aircraft were allocated between the flight deck and the hangar bay. The second incorporates the specific allocation of aircraft used in the *Nimitz* Surge.

Aircraft turnaround—time available

Three key factors constrain turning around multiple aircraft:

- Each squadron had only one bomb crew on the flight deck to load ordnance on their aircraft. Loading of squadron aircraft must be done in sequence.
- Special servicing cannot be done in conjunction with fueling and ordnance loading.
- Electrical connections cannot be made during fueling.

While some turnaround functions were conducted while aircraft were being launched and recovered, they were limited. The flight deck crews are most active in the period between recovery and launch. During the Surge, the average time between the conclusion of recovery and the start of launch was twenty-five minutes for 1+00 cycles; thirty-five minutes for 1+15 cycles; forty-two minutes for 1+30 cycle; and fifty-seven minutes for 1+45 cycles. As figure 51 shows, the time

between recovery and launch does not grow commensurate with the cycle time. For every fifteen minute increment in cycle time, the time between recovery and launch grows by about ten minutes.

We show our estimate of the processing capacity of the turnaround crews in table 35. These estimates are based on the observed times to fuel, arm, and spot individual aircraft during the *Nimitz* Surge. The processing capacity for the F/A-18 squadrons is larger than that of the F-14 squadron. This result is because turnaround for the F/A-18s could begin as soon as the aircraft had shut down, since respots typically were not required. For F-14s, though, turnaround typically did not begin until after the recovery was complete. In addition, turnaround of the F-14s typically was more involved and time consuming.

Figure 51. Time between recovery and launch

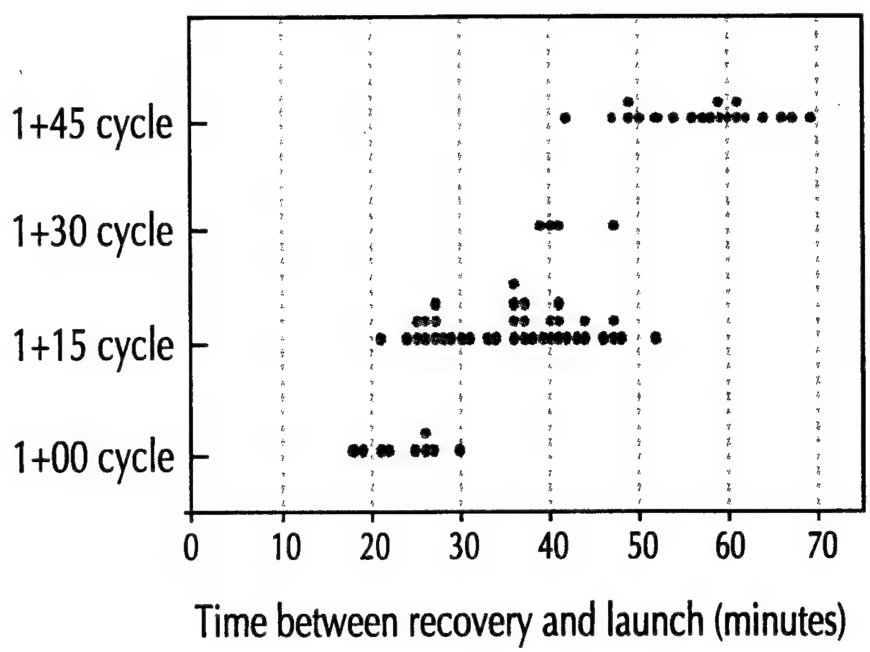


Table 35. Predicted number of aircraft that could be turned in one cycle

		Number aircraft turned		
Cycle time	Cycles in Surge	F-14	F/A-18	Total
1+00	9	1	6	7
1+15	38	2	9	11
1+30	4	2-3	12	14-15
1+45	19	3	15	18

Our analysis of the turnaround capacity results in an estimate of 155 (ten additional) F-14s and 744 (101 additional) F/A-18s that could have been readied for launch in the time allotted.[26]

Aircraft turnaround—MC aircraft available on the flight deck

Using the records from the cat/trap log, we tracked individual aircraft from event to event, establishing how soon after recovering they flew again. Figure 52 shows the elapsed time aircraft spent on the flight deck. Keep in mind that turnaround operations were conducted within this period, so this time is longer than the actual time spent to turn the aircraft around. Figure 53 shows the percentage of aircraft (by type) that recovered, turned around, and launched in one, two, three, or four cycles. The data show that typically the F/A-18s were turned around in one cycle on the flight deck while the F-14s were turned around in two cycles. Other aircraft typically were turned around in three cycles.

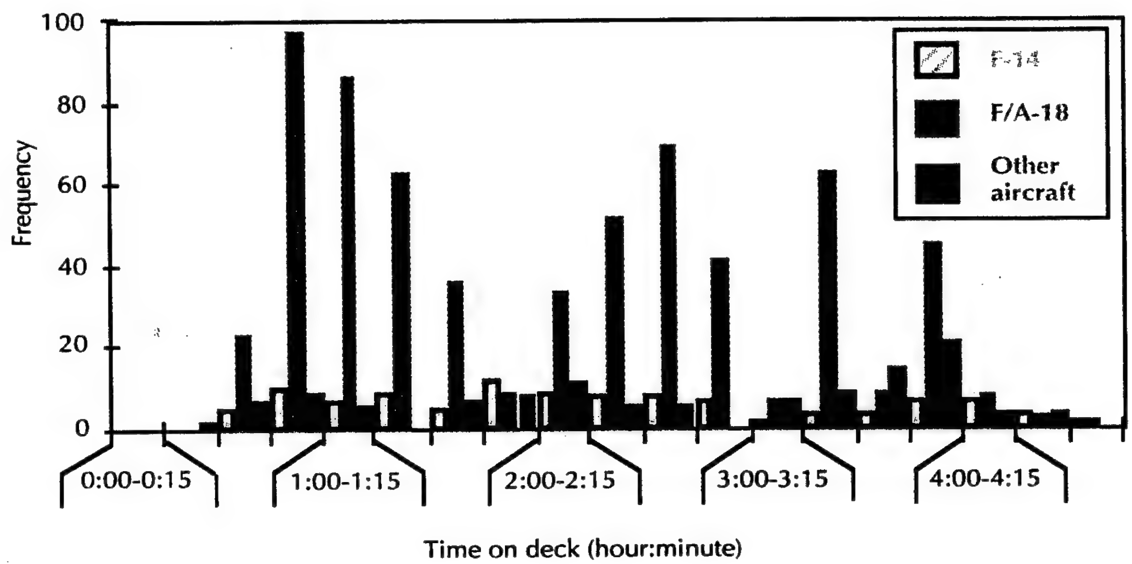
The turnaround time available within a single cycle was shortest for the F-14 for two reasons: taxiing F-14s to their spots during flight operations was difficult;[27] and F-14s typically recovered last and

26. Because the 1+45 cycles were frequently the periods when *housekeeping* activities were conducted, giving less time for turnaround tasks, we considered an excursion where the number of strike/fighters that could be turned in a 1+45 cycle was the same as that during a 1+30 cycle. This resulted in 145 (no additional) F-14s and 684 (forty-one additional) F/A-18s that could have been readied for launch in the time allotted.

27. During deployment, USS *Nimitz* changed its procedure to recover F-14s first and spot them on the fighter line. This recovery sequence and spotting location allowed F-14 turnaround operations to commence shortly after the F-14 landed.

launched first.[28] Because the turnaround crews had to wait for the F-14s to be spotted before they could begin their tasks, F-14 turnaround functions usually began after the recovery was complete. In addition, F-14s have a lower reliability and can be more difficult to repair than F/A-18s. Thus, the aircraft that required the longest time to turn around were the last to begin the process. All of this combined to make the F-14s more likely to be turned in two cycles rather than one.

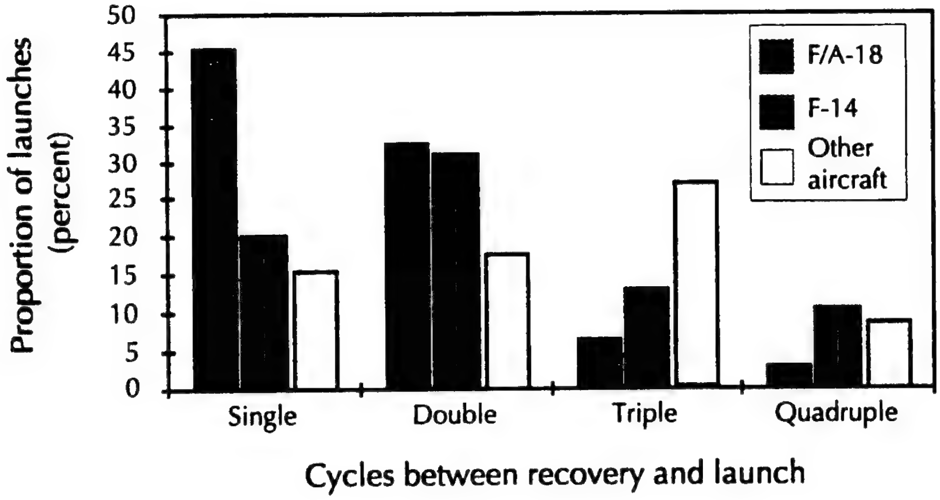
Figure 52. Aircraft elapsed time on deck



Statistics describing the strike/fighters that were readied for launch within a single cycle are shown in table 36. On average, fewer aircraft were turned around during the 1+45 cycles than during the shorter cycles. One might expect with more time, a larger number of aircraft would be turned around in a single, long cycle. As planned, however, the flight deck crews were conducting other tasks (such as respotting the flight deck and conducting FOD walk-downs) during the longer

28. This launch sequence plan was to take advantage of the F-14's greater airborne endurance over that of the F/A-18C.

Figure 53. Number of cycles in which aircraft were readied for launch[a]



a. Because the cycle times varied throughout the Surge, the independent axis does not correlate to time. Also, the data for each aircraft type do not add to one-hundred percent because some aircraft were returned to service after periods beyond four cycles (usually because the aircraft were undergoing maintenance).

cycle times, so the entire time was not devoted to readying aircraft for launch. Concurrent with these aircraft, the flight deck crews were also readying other aircraft for launch, on average processing an additional five F/A-18s and two F-14s per cycle.

Table 36. Strike/fighters readied for launch within a single cycle

	Number strike/fighters turned		
Cycle duration	Average	Minimum	Maximum
1+00	5.4	3	10
1+15	4.9	1	10
1+30	5.0	3	7
1+45	4.2	1	7
Four-day Surge	4.8		

The average cycle time was 1+22. Using the estimates in table 35, we assumed at most thirteen strike/fighters could be readied for launch on each cycle. Extracting the strike/fighters readied over several

cycles (on average, about seven) results in an estimate of six F/A-18 aircraft that could be turned around on average in a single cycle. We assumed at most seven strike/fighters could be readied within a single daylight cycle and at most five during a night cycle. We based this assumption on two reasons: the operating tempo was higher during the day than the night; and night operations are more challenging for flight deck crews than daylight operations. For cycles in which time to ready additional aircraft was available, we examined whether MC aircraft that could have been readied were on the flight deck. Under these assumptions, between fifty-two and sixty-eight additional strike/fighters could have been readied for launch.[29]

Summary of sortie generation capacity

We summarize our estimates from the previous sections in figure 54 for comparison to each other:

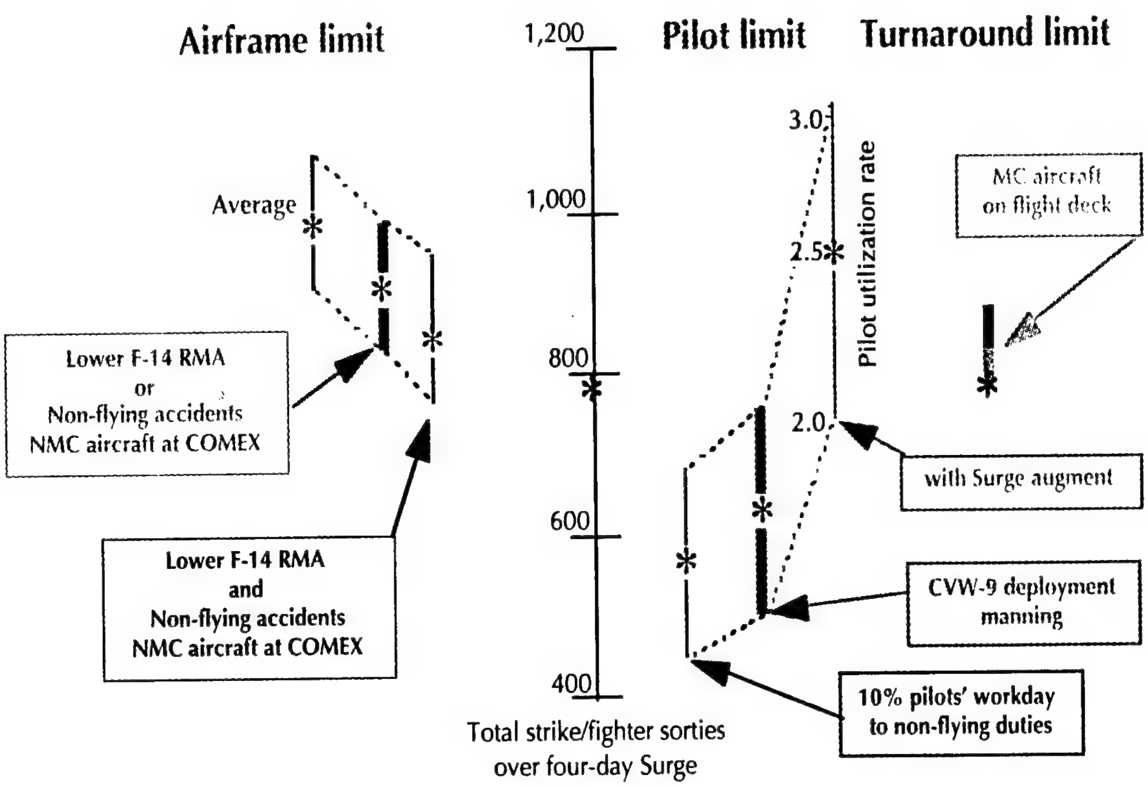
- Airframe limitations: For the limits imposed by the airframes, we include the possibility that not all strike/fighters may be MC at the beginning of a surge or that aircraft may be lost to non-flying accidents. (This is equivalent to excluding one aircraft per squadron from use). The airframes limit sortie generation to between 835 and 990, with an average value of 905.
- Aircrew limitations: Airframes need aircrew to fly them. We show in figure 54 the limits imposed by capping the pilot utility rate somewhere between 2.0 and 3.0. We show the resulting limits to sortie generation for manning levels comparable to that of CVW-9 during deployment and during the Surge. We also include an assessment of the need to allocate ten percent of an aircrew's workday for manning levels at CVW-9's deployment level. With the Surge augmentation and a cap on

29. Different assumptions about the number of aircraft that can be readied in a single cycle will change the estimate of the turnaround capacity of the flight deck. Appendix C (Volume 2) contains the turnaround estimates under different assumptions.

the pilot utilization rate of 2.5, sortie generation was limited to 943.

- Turnaround limitations: Manned aircraft need to be readied for launch. Incorporating our estimates of the turnaround capacity of flight deck crews, turnaround of aircraft limited sortie generation to between 838 and 888.

Figure 54. The limits to sortie generation



We can draw several conclusions from our analysis:

- Turnaround processes were the most constraining factor, followed by pilot availability, and lastly, airframe availability. In hindsight, it might have been possible for the USS *Nimitz* flight

deck to process 50 to 100 additional strike/fighter sorties over the four-day Surge.

- To increase sortie generation beyond that seen in the Surge, the number of ordnance crews would need to be increased to allow more crews to work the same shift. Steps would need to be taken to ensure that the flow of ordnance to the flight deck could keep pace.

- Had the pilots not been augmented, they would have been the most constraining factor.

- Using an Operational Strike Planning Cell greatly reduced the workloads of the aircrew, thus enabling them to focus on strike execution. As a consequence, higher pilot utilization rates could have been achieved.

- Augmentation for aircrew should include not only qualified aviators but also officers who could substitute for aviators in such non-flying duties as watch standing. Freeing qualified aviators from non-flying duties increases their potential rate of strike mission execution.

- As expected, the airframes were the least limiting factor. Based on our observations and calculations, the CVW-9 F/A-18s, aircraft that lend themselves to quick and efficient maintenance, could have generated more than an additional 150 sorties. There was no need to augment the airwing with additional F/A-18s (at least not in the low attrition scenario of the *Nimitz* Surge).

- While the *Nimitz* Surge benefited from an exceptionally short supply chain, simulation modeling indicated that with longer logistics pipelines, airframe availability should not be a constraint. However, in situations where the logistics supply chain is longer, key spare parts (such as the F/A-18 video recorder and APG-73 radar receiver) should be considered for higher inventory levels and higher cannibalization rates should be anticipated.

- For F-14s, the constraint of pilot utility rate is close to that of aircraft turnaround. There is little excess capacity to compensate

for unexpected losses of pilots. We recommend, therefore, that additional augmentation for the F-14 squadron be considered.

Sustainment of high-intensity flight operations

The *Nimitz* Surge lasted ninety-eight hours. There are hard constraints to the length of time a carrier and its embarked airwing can maintain a high-intensity operating tempo without pausing. The carrier will eventually deplete its magazines of ordnance and consume its supply of the JP-5. Periodically, flight operations must be halted to conduct necessary maintenance. There are soft constraints as well—the endurance of the individuals aboard. Considering these factors, we project that USS *Nimitz* and Carrier Airwing Nine could have sustained the Surge operating tempo for another twelve to twenty-four hours.

The nominal inventory of a deployed nuclear-powered carrier includes 804 Mk 82, 900 Mk 83, and 200 Mk 84 bombs [3]. Additional ordnance is carried in the battle group AOE. At the rate of the ordnance expenditure of the Surge, twenty-two hours after the Surge ended USS *Nimitz*'s magazine would have been empty of Mk 82 and Mk 83 bombs (figure 55). USS *Nimitz* and CVW-9 could have tapped their inventory of Mk 84s to continue operations. Had they elected to do this, the operating tempo would have been reduced because Mk 84 loading requires special equipment and is far more involved than loading lighter bombs.

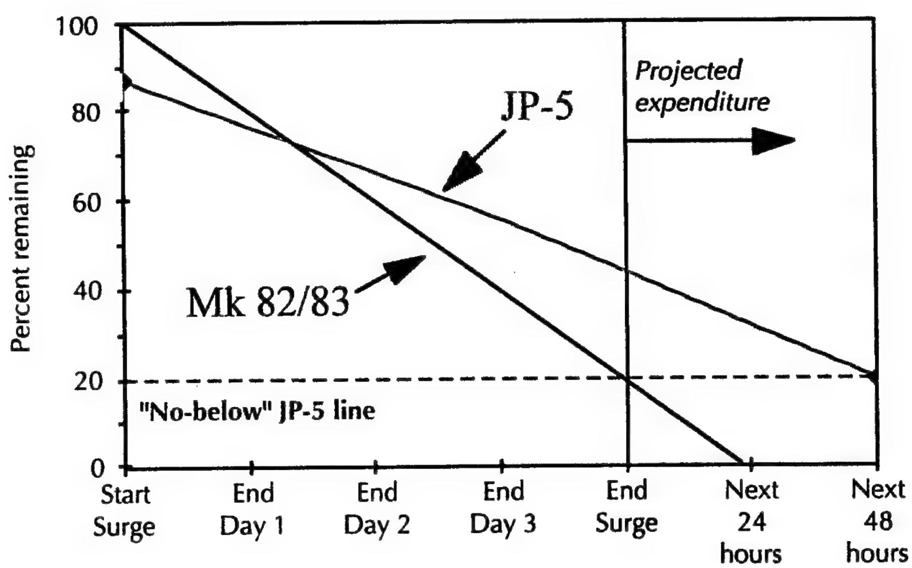
The strike/fighter bomb racks required cleaning after the second day of the Surge. Ordnance crews switched to loading the other set of weapons stations and left the soiled racks in place. This postponed the need to remove and replace the racks. Had the Surge continued much longer, strike/fighters would have had to have been removed from the line to perform this cleaning, and sortie generation would have decreased.

USS *Nimitz* replenished her aviation fuel stores the evening of Saturday 19 July, starting the Surge with 3,111,732 gallons of JP-5. At the completion of the airwing fly-off following the Surge operations on Thursday 24 July, USS *Nimitz*'s fuel was down to 1,516,590 gallons, or

42 percent of her maximum capacity (3,595,778 gallons). In peacetime, carriers typically schedule an underway replenishment before JP-5 stores fall below sixty percent capacity; in wartime, JP-5 levels are allowed to fall lower. But using aviation fuel below twenty percent is not recommended for a few reasons. First, the purity of the fuel becomes suspect. Also, to retain buoyancy control of the carrier, water must be added to the tanks when fuel states are low. Doing so requires extensive maintenance actions to remove water from the fuel delivery systems and tanks.

Figure 55 shows the consumption rate for JP-5 in the Surge.[30] With the consumption rate observed at the end of the Surge, another 430,000 gallons of JP-5 would have been consumed in an additional twenty-four hours, reducing USS *Nimitz*'s fuel reserves to 1,086,590 gallons, or thirty percent of capacity. In another twenty hours, USS *Nimitz* would have been at the twenty percent level.

Figure 55. Ordnance and JP-5 consumption



30. JP-5 consumption is discussed further in the *Operations during the Surge* section of this report.

Although airframe readiness declined over the first three days for most type/model/series aircraft, readiness climbed on the final day. This suggests that airframes were not on the brink of exhaustion, and that—from an airframe perspective—the Surge could have continued.

During the Surge, parts in high demand and low availability (such as the F/A-18 video parts and APG-73 receiver) were expedited from shore stations to the carrier. These parts arrived by COD within a few hours of when they were requested. The twelve-hour wholesale logistics response time experienced during the Surge is an exercise artificiality. When West Coast carriers are deployed, they average five to six days for receipt of high priority parts and twenty days for low priority items. Simulation modeling indicates that when the response time is decreased to just a few days or less, there is little difficulty in supporting high-intensity flight operations.

Eventually, scheduled maintenance must be performed, which would disrupt and, in some cases, halt flight operations. Most of the ship's and aviation preventive maintenance schedules were worked around the four-day Surge period. Weekly, monthly, and quarterly maintenance activities were either performed before the Surge began or scheduled for after the Surge concluded. The sustainability of this Surge operating tempo is bounded by these maintenance schedules. At the least, weekly PMS activities would have prevented the carrier and the airwing from operating for more than three additional days before the conduct of scheduled maintenance would have affected flight operations.

The more difficult constraint to measure is that imposed by personnel; that is, the time before exhaustion overtakes individuals. In previous high-intensity flight operations, the capacity to generate sorties was usually limited by people. In the *Nimitz* Surge, it was not.

We found no evidence that general fatigue was present among aircrews. In fact, by every objective measure we considered, pilot performance improved during the Surge. The only factor we found that contributed to aircrew fatigue was the sudden shift from day to night flying and the subsequent effects on shifting work/sleep patterns.

Some personnel groups were undermanned and fatigue was evident by the final day of the Surge. Specifically, the catapult and arresting gear operators and the maintenance troubleshooters were undermanned. (Neither group received augmentation.) Flight deck crews were fatigued, as indicated by the increased number of combat FOD walkdowns on the last day of the Surge, the observed increase in the number of people crossing the foul deck lines during flight quarters, and the increase in aircraft suspends while on the catapult.

Reference [17] reports an increase in physical and especially mental fatigue by the fourth day of the Surge. The hardest hit group was those in positions of authority. Most of these people do have individuals within their command to whom they can transfer authority while they rest. Over the four-day Surge, most leaders accumulated a significant sleep debt. Although they were relieved for short periods, their stress was evident by the end of the Surge.

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